Preparation of the Conceptual Design

of complete isolation, re-cultivation of I and II cells in Tbilisi Household Solid Waste Landfill, arrangement of gas collection system and turning biogas into the valuable product, preparation of the Conceptual Design the in-service cell III in accordance with the exploitation-development and final re-cultivation, procurement organization, construction supervision and project management

Volume 2

Conceptual Design

Part I

Project: NAT190002890

Reporting period: 22.05.2019 – 22.05.2021

September 2019

Contents

Abbreviations

HDPE - High density polyethylene

PEH - Polyethylene

PN - Pression Nominal

Ltd. – Limited Liability Company

Introduction

The basis of the curent document is the State Procurement Agreement N30-212 signed between Tbilservice Group Ltd and Geo-Consultant Ltd on May 22, 2019, with the aim of improvement of waste management at Tbilisi's Didi Lilo Household Solid Waste Landfill by developing systematic approaches in line with national legislation and European standards.

The Project Beneficiary	Tbilservice Group Ltd
Duration	22.05.2019 – 21.06.2021
Cost	1 390 646.52 GEL (including VAT)
Place of implementation	Tbilisi Solid Waste Household Polygon
The Executor	Geo Consultant Ltd
The Financial supporter	The municipal budget

The Conceptual Design of the horizontal and vertical gas collection system, rehabilitation and restoration of the destroyed slope in the southern part of the I and II cells, as well as the I, II and III cells, an expanded section of the I and II cells of the Landfill

By the time the current document is created, the I and II cells are already filled, interconnected and partially recultivated. Therefore, in the future we will perceive them as the single object.

In the process of filling the cells with wast, were made 100 vertical gas collecting wells, in which 160 mm diameter HDEP pipes were laid, with adapters 160/110 mm. The wells do not form the single gas collection system and the gases are emitted directly into the atmosphere.

As the result of the recultivation on the I cell of the Polygon, the waste slopes are treated with the slope of 1: 3 and less. The southern slope of the I cell is steep, collapsing and falling to the bottom of the upper fertile layer cell of the HDPE membrane. The reason for this is the inefficiency of the landfill degasation system, which causes accumulation of the gas beneath the membrane, its convex, and collapse of the upper layers.

To correct the situation It is advisable to take the following measures:

1. Dismantling the HDPE membrane from the surface of the landfill;
2. Additional formation / compaction of the southern slope;
3. Improvement of the landfill gas extraction using existing gas wells;
4. Install the horizontal landfill gas collection system on the Polygon (in this case the term "horizontal" should be used to distinguish it from the existing vertical gas collection system);
5. Improving the leachate recirculation system to reduce the intensification of biogas production and reduce the amount of leachate, purified by Reverse Osmosis;

Upon completion of the construction work on the above mentioned nodes, the cell surface should be covered with the leveling layer with the thickness of 0.15 m; The top insulating layer of the cell should consist of the waterproof layer, for which recommended to use bentonite with the density of 400 g/m^2. Its surface will be covered by the 0.5 m thick

layer of local fertile soil, which will then be planted by hydro-seeding. Fig. 1 shows the top layer of the cell insulation and its section after the rehabilitation.

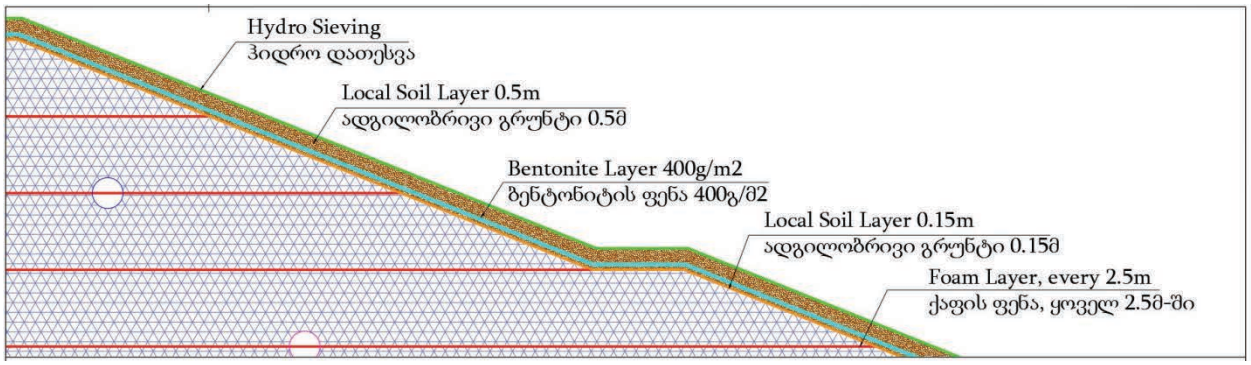


Fig. 1 Top layer of cell insulation and section after the rehabilitation

Fig. 1 gives the preliminary design, which should be done in accordance with paragraphs 1 and 2. The additional work is also planned to form the 1: 3 south slope corresponding to the formation. The additional slope reinforcement will be achieved by terasing the cell surface. The terrace will be 3.0 m wide and will be arranged in the serpentine form throughout the cell, up to its highest point.

The Short analysis: *2010 The feasibility study document provides for the installation of 700 gas wells throughout the lifecycle. It is not mentioned what type of gas supply system is set by default (vertical or horizontal). The study of the design area revealed the existence of 100 units of vertical gas collecting systems on the I and II cells of the Polygon and identified the problem associated with the disintegration of the southern slope of the I cell. This is due to ineffective extraction of biogas and improper compaction of waste slopes during the operation phase. The Conceptual Design developed by the consultants provides for both the parallel installation of the horizontal gas collection system and updated procedures for active filling of cells and optimal waste compaction.*

Landfill gas collection, extraction and utilization system

After reclamation of the landfill surface, the final formation of the biogas extraction system vill be performed, which is presented in Fig. 2. The Landfill gas collection system will combine the I and II cells, the vertical and horizontal Gas collection systems and the horizontal Gas collection system of the active III cell, which will be installed in parallel with the waste disposal. Subsequently, with the expansion of the Polygon, incorporation of new cell systems into the system is contemplated. The each cell will have its own gas collection system and the gas regulator, which will be located nearby of the each cell and connected to the gas collector. The elements of the gas collection system (wells, gas pipes, collectors) will be equipped with the gas release and condensate collection system. It's important to consider

the formation of the large amount of condensate, as the result of the gas condensation in gas pipes.

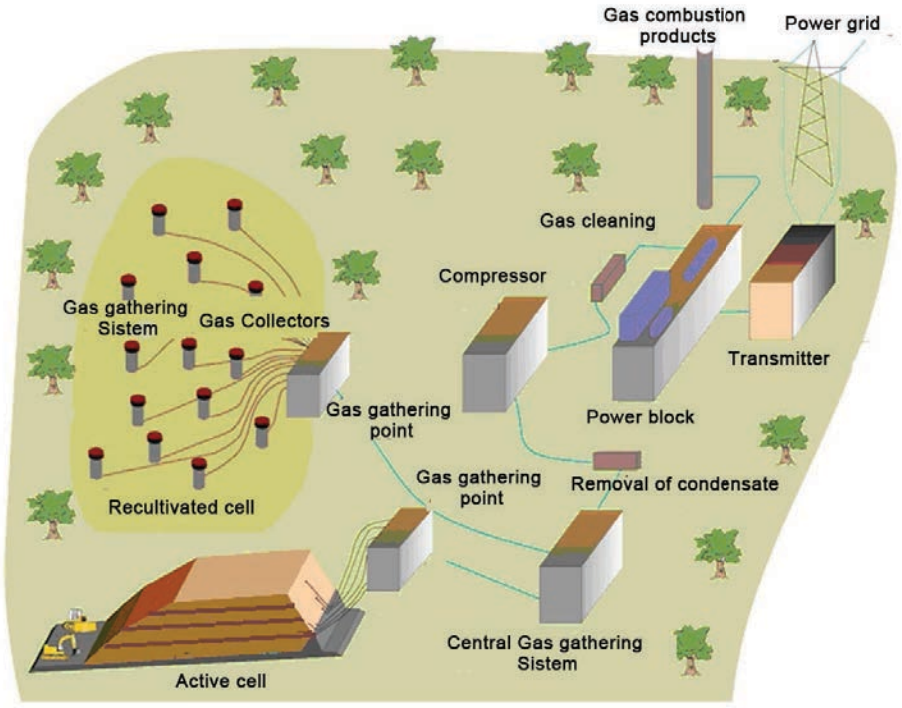


Fig. 2 The scheme of the Landfill gas collection, extraction and utilization system

To extract the biogas from the landfill, will be provided the blower (compressor) station, which by creating the vacuum will ensure the removal of gases created in the waste layers. The amount of created vacuum should be proportional to the rate of biogas discharge. The gas collection well or horizontal gas collection pipe around itself creates the kind of discharge zone, also called as the capture zone. The size of the discharge zone depends on the blower parameters (the greater the vacuum, the wider the discharge zone), the bandwidth of the waste, the intermediate overlap of the waste layers, the location of the leachate, the final insulating layer of the cell, and other factors. As the rule, when the efficiency of gas assembly is importent, it is advisable not to create the system where the distance between the wells and the gas pipes will be large, requiring operation in strong vacuum conditions, but to develop the tighter network of gas collection points, that will operate in relatively low vacuum conditions. This is the best experience of landfill gas management, which is economically justified when using the biogas collection systems.

It is established that when using landfill gas extraction equipment, the most optimal vacuum rate ranges from 0.25 to 0.65 m for the water column, at which the biogas discharge is maximal and the outside air penetration is minimal. During poor sealing of the top insulating layer of the recycled Polygon, the outside air penetration causes the change in the composition of the landfill gases, with an increase the oxygen concentration, resulting in biogas heat loss.

The biogas collected from the Polygon will move to the gas collector and gas regulator via the system of collectors. This element is the container that contains the so-called "Comb", to which collectors are connected. Each collector is equipped with the condensate generation and supply system. If necessary, the gas composition at the inlet can be adjusted if we shut off the valves one-by-one; In addition, each collector will be equipped with the monitoring device that will determine the amount of methane in the biogas. Fig. 3 shows the gas collecting points.

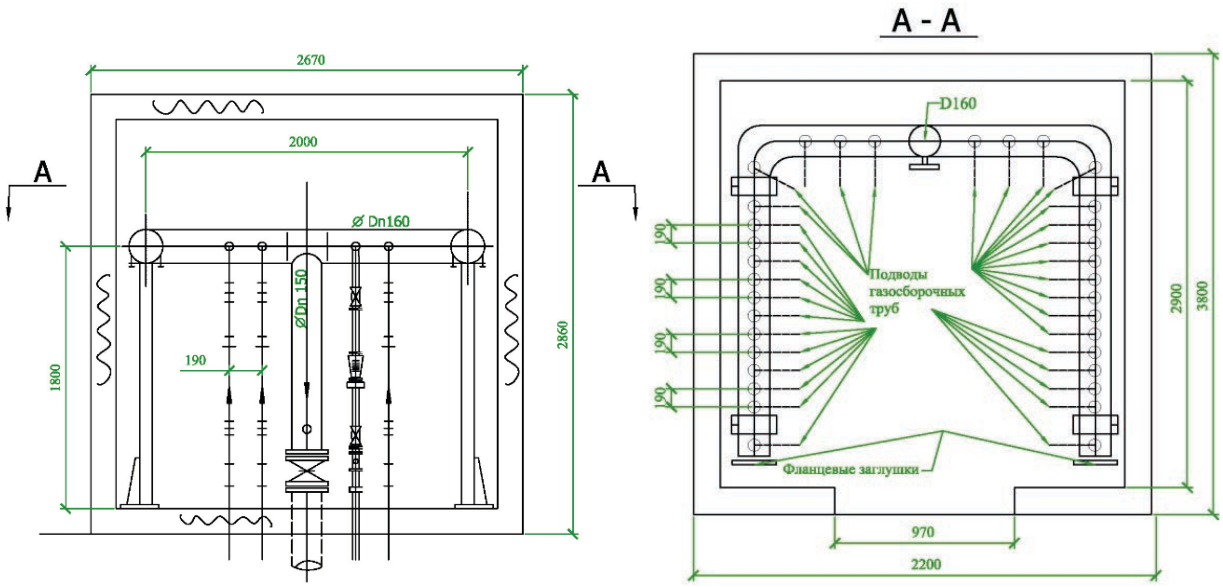


Fig. 3 The gas collecting points

From the “Comb”, the biogas will move to the main collector. When designing the main gas pipeline, it’s necessary to take into account the presence of the condensate in the system that arises from the cooling gases. The gases emitted from the Polygon have the very high temperature and humidity, and when it enters in the gas pipe, the gas temperature drops, resulting the large amount of condensate. For example, during the extraction of 100m^3 of landfill gas, up to 1 m^3 of condensate is produced. This is why removing the condensate with the special device is so important.

The presence of condensate in the pipeline can create the number of problems during biogas extraction. For example: to create the water jams in gas pipes. To avoid this, it's necessary to install condensate-collecting wells at the lowest point of the system. Equipment used for condensate removal shown on the Fig. 4.

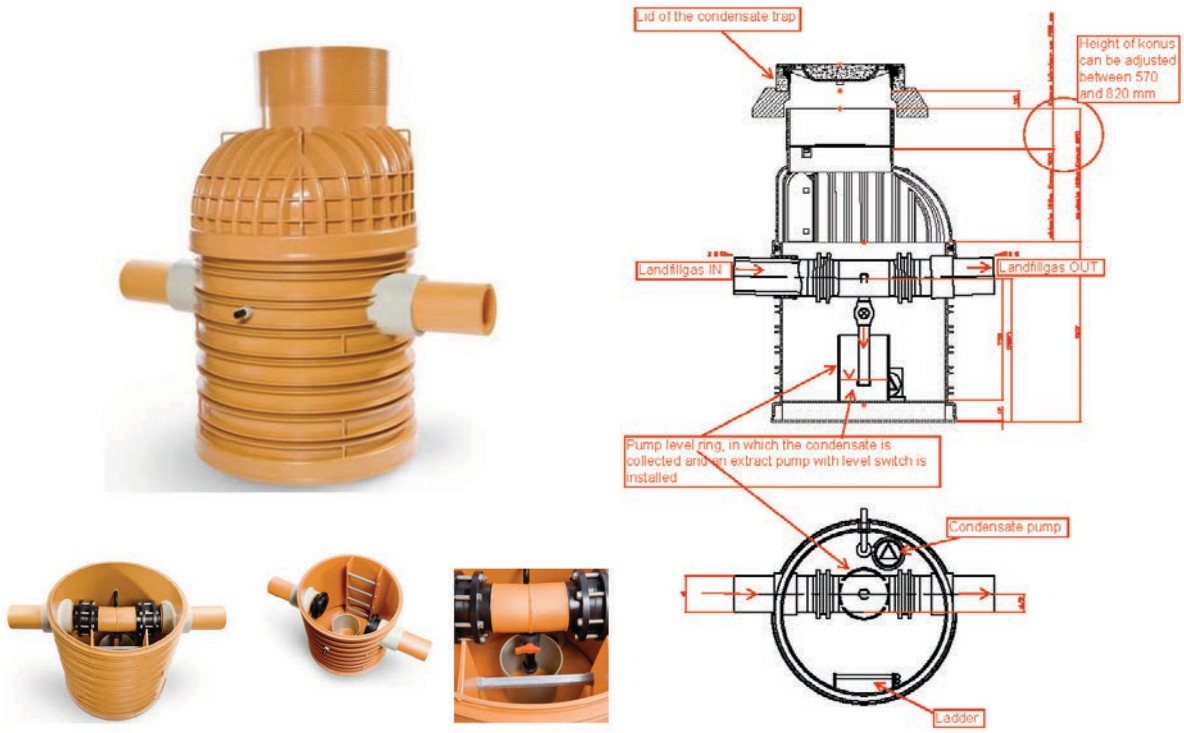
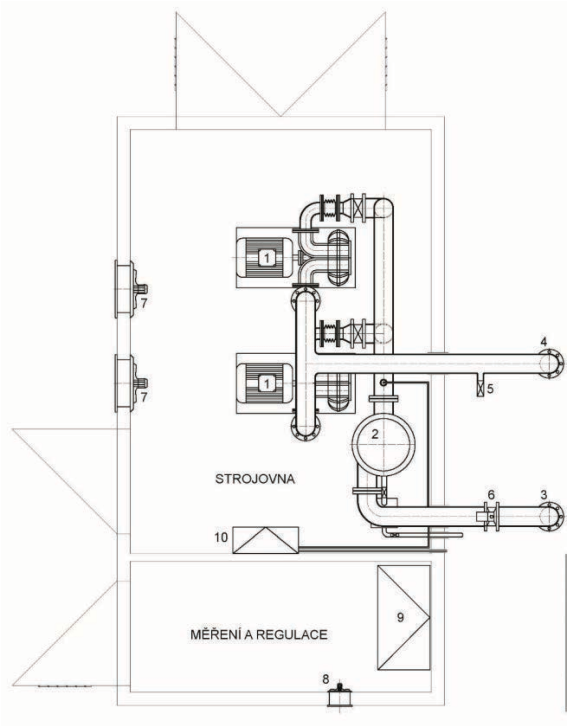


Fig. 4 Condensate removal equipment and its construction

The condensate collector wells are identified on the main pipeline when developing the gas pipeline project. The blower is installed at the compressor station, which creates the necessary vacuum in the gas-gathering system and the compressor that raises the gas pressure. If needed, the biogas storage tank - gas-holder can be placed. Schematic image of compressor station given on the Fig. 5.

Different types of landfill gas can be consumed. At the first stage of the project, it is recommended to burn the Polygon gases in the Torch device; Later, it can be used the co-generation equipment that generates from the biogas electricity and heat energy. Fig. 6 shows the Torch device for burning Landfill gas equipped by compressor.



1. Blower CL 20/21 Sp. 150 m^3/h;
2. Filter 50 mk m;
3. Main gas suction;
4. Main gas Vent;
5. Emergency vent hood;
6. Electric hood with emergency shutdown function;
7. Vent of the mechanical section;
8. Operating vent MaR;
9. Shield for the management and monitoring;
10. Shield for the Analyzer

Fig. 5 Compressor Station

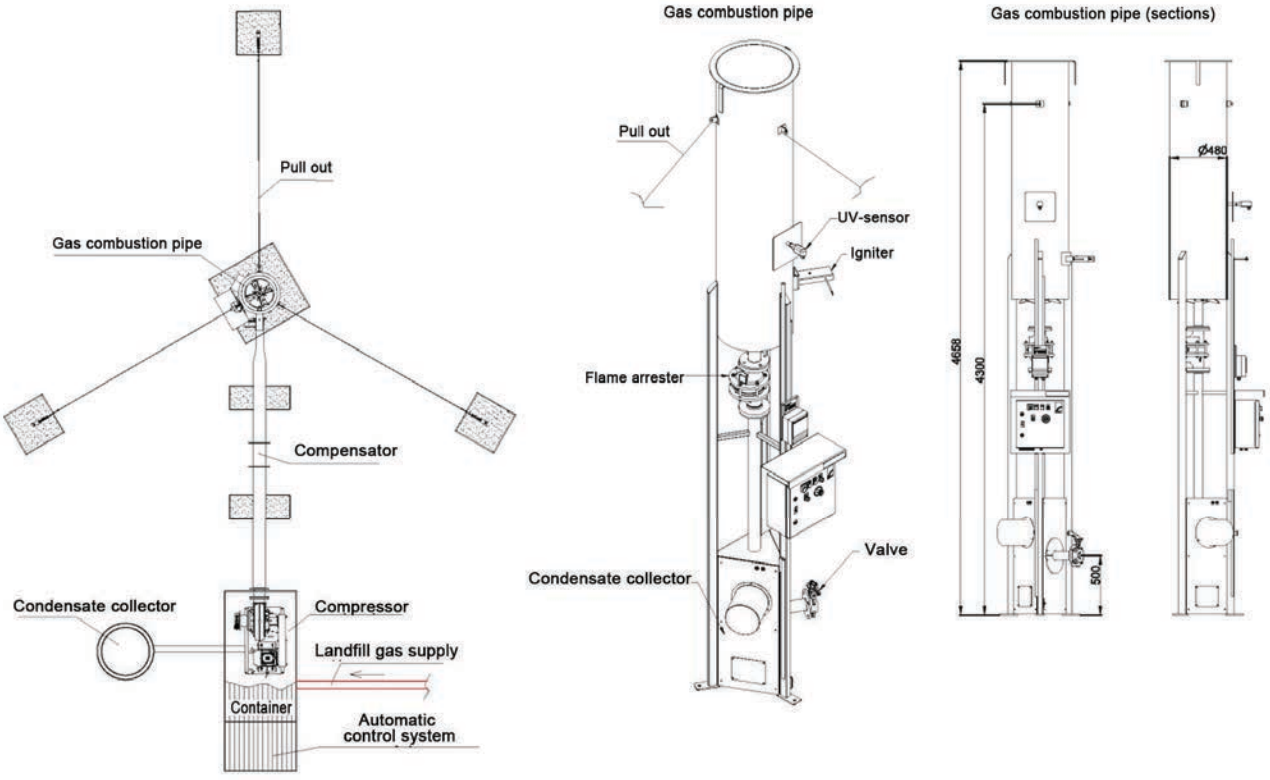


Fig. 6 Torch device for burning Landfill gas equipped by compressor

Installation of the horizontal gas collection system on the I and II cells of the landfill

The “Horizontal” gas collection system should be laid in accordance with the Fig. 9. The “Horizontal” gas collection system involves the extraction of landfill gases from deep layers of waste. It’s essential that the first row of gas pipes be located 4-6 m above the level of possible accumulation of filtrate. At the same time, after recultivation of the cell, its surface should not be damaged, as all the output pipes are located at the bottom of the cell.

In the case of the "Didi Lilo" Polygon, only one layer of gas collecting pipes can be fitted; However, they are not laid exactly horizontally, so we call this system the conditionally horizontal.

In order to install the gas collecting pipes, in the waste layers will be made the 1.5-2 m deep trench, the banks of which will be fastened with removable panels to prevent collapse. The bottom of the trench will be leveled to the level indicated in the Disaign of the construction biogas collection system. The waste is not compacted at the bottom of the trench, but retains its natural density. At the bottom, along the removable panel, the 20 cm thick layer of 12-40 mm fraction washed gravel is laid. Above the layer of gravel, will be placed specially perforated gas collection HDPE pipes (usually PN10, size D100/10), which will collect gases from the lower layers of the waste. The end of the pipe located under the waste will be closed by the valve. The pipe will be covered with the 20-cm thick layer of grave. For the gas extraction, to the gas collecting pipes will be connected the smooth-walled D90 mark (PN4 PEH) pipe. After completion of the work, the the removable panel should be removed and the trenches should be filled with 0.5 m thick layer of the wast (see Fig. 7).

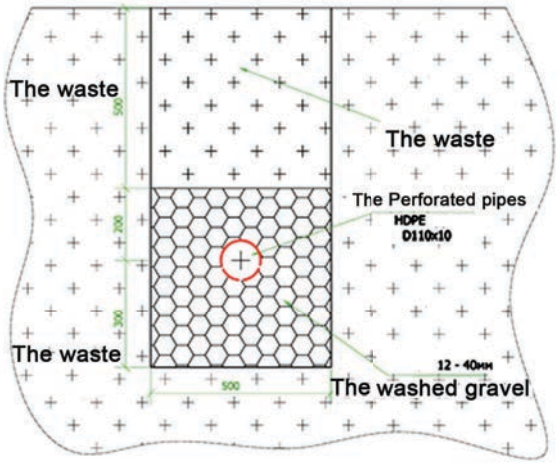


Fig. 7 Layout chart of the Gas collection pipe

It should be keep in mind, that the gas collection pipes, located under the waste layers undergo significant vertical loads, which is further increased by the uneven distribution and fractionation of the waste. Taking into account these factors, pipes with the appropriate technical characteristics and their perforation method should be selected. Perforation should be made at the bottom of the pipe with 8 mm in diameter holes, with frequency varying from 10 to 30 holes per meter (see Fig. 8).

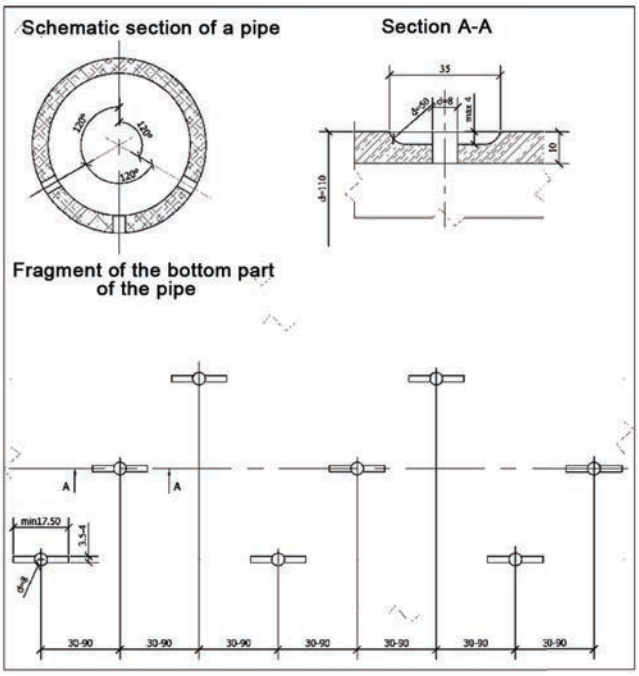


Fig. 8 Perforation pattern of the Gas collection pipe

The pipes should be connected to each other in such way, that ensure the same rates of pipe rupture in the joints. This will allow us to avoid breaks at the joints, since the entire pipe system is under significant load. The connection of the perforated pipe with smooth-walled pipes and the scheme of their exit from the Polygon body is shown in the the Fig. 9.

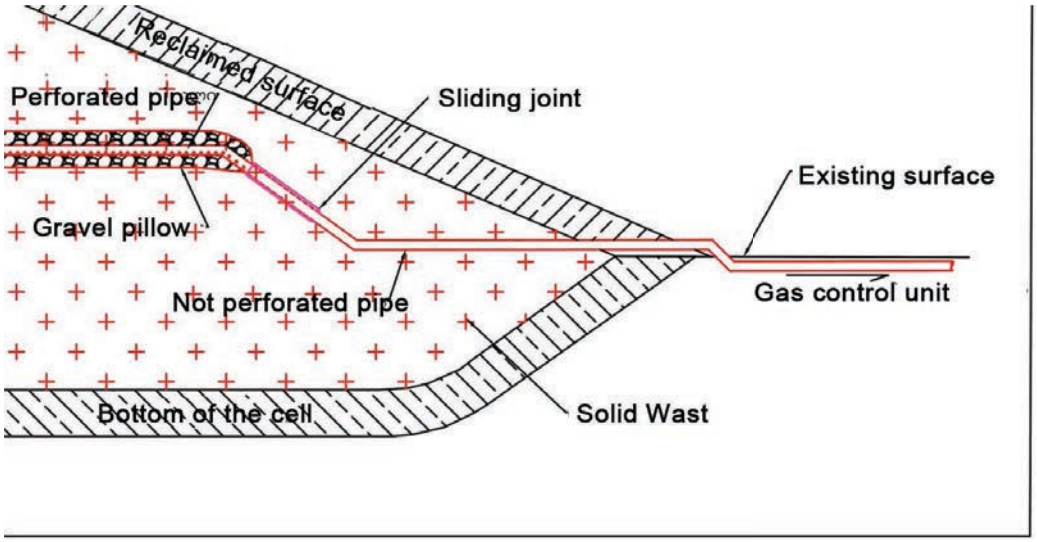


Fig. 9 Exit of the Gas collecting pipe form the Polygon body

When laying pipes, the permissible slope requirements should be taken into account. Minimum slope of the pipe should be not less than 0.2% and the best option is 2%. This is the case when the pipe is sloped in the direction of the gas movement. The need to comply with the slope is due to the presence of condensate in the pipes and it must ensure the movement of condensate in the pipes. At the same time, when laying pipes the formation of vertical bends not should be allowed, because that this can cause water jam and, therefore, disruption of gas circulation.

At the design stage of the gas-collecting system, the diameter of the gas-collecting perforated pipes and smooth-walled pipes are determined. Blower settings, pipe lengths and allowable pressure losses in the pipe shall be taken into account. The final decision on the parameters of the pipes in the system is made based on the results of the hydraulic calculations of the pipeline system.

The horizontal gas collection system on the I and II cells of the landfill

Biogas is collected and produced at the I and II cells of the landfill through the 100 vertical gas collection wells. They are not equipped with blocking valves and are completed with pipes with the diameter of 110 mm.

For the normal functioning of the wells, there are necessary equip them. Before installing the well, should be check the clay cap around the pipe, and if necessary, it should be expanded and compacted. The concrete well stands on the expanded part of the clay cap. Finished gas wells are shown in the Fig. 10.

The pipes located in the well should be shortened to size and reinforced, which provides access to the pipe (with shut-off valve) and connection to the gas collection pipe (see Fig. 9, Node "A").

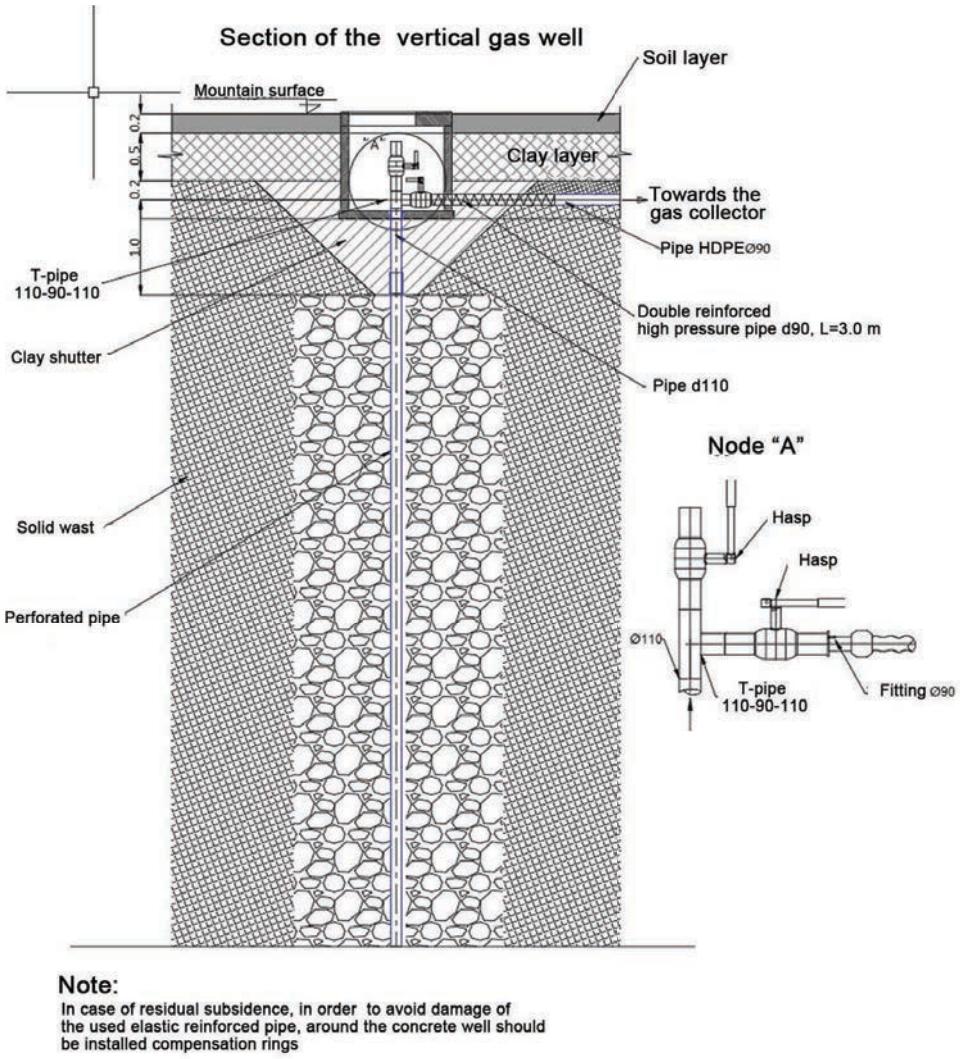


Fig. 10 The vertilac gaz well section

Access to the central well pipe is necessary to control the level of the gas concentration, temperature, flow rate, static pressure and leachate (if he gets into biogas) through field equipment. The gas supply pipe is the reinforced by the two-layer high pressure pipe. This is necessary, that the well does not settle due to settling of the waste. The second end of the pipe is connected to the gas pipeline. The gas collection pipe, in turn, is connected to the gas collector. Connection to the collector well is carried out by the "Bush" method; The optimal number of wells connected to one collector is 10 units.

The system of the gas extraction from the vertical gas collection wells is shown on the Fig. 10.

Important notes

Given the conditions at Didi Lilo Polygon (equipping and completing equipping the existing system), there is the problem of collecting gas from those gas wells, which located on the opposite side of the collection point. In our case, the collection point is located in the southern part of the landfill. Northern Gas wells are located on the opposite side of the landfill hill. Due to the requirements for the condensate inlet pipes slope, it's impossible to collect gas from the north side without vertical inflection, from gas collection wells, in accordance with the reclaimed relief of the landfill hill. Therefore, it's recommended to install additional condensate collectors on the north of the landfill, and ultimately for the proper functioning of the system 5 condensate tanks should be installed around the cells. They should be joined collectors coming from biogas wells located in the north, and the second end of horizontal gas pipelines, which will combine with the condensate collectors of the northern part, and will move into the volume of condensate. Collected condensate by the pumps will be pumped out to the leachate collection system.

Collection and extraction of landfill gases from the III cell

The Conceptual Design of the III cell developed by the consultants presents the possibility of the installing the horizontal gas collection system. The principle of laying pipes is similar to the arrangement of horizontal gas collection systems described for the I and II cells, except that in the case of the III cell the pipes will be laid in parallel on the compacted and leveled waste surface, parallel to the operation, and 50x50 cm size trenches will be dug. Subsequently, the trenches will be filled with drainage material and the pipes will be laid in accordance with the specified inclination. The pipes will be located at the height of 7.5 m between the waste layers, with the checkerboard pattern. The optimal distance between the

pipes will be 20 m. The layout of the pipes in the cell and the cut are given in the Fig. 24 and 25.

In the western part of the cell there will be installed the gas gathering and gas regulating units. Their construction is similar, to that described for the I and II cells. Condensate also will be collected here. The gas line coming out of the III cell joins the gas line coming out of the I and II cells (see General Plan, Fig. 2). After joining the pipelines, the biogas will be transferred to the site of consumption.

The requirements of the parameters of the pipeline and condensate separation systems provided for the III cell are similar to the requirements of the I and II cells.

Waste humidification system

Infiltrates moisturize the recirculation system, promoting hydrolysis from the organic fraction due to the intensification of the biogas production. In I and II cells, in the process of rehabilitation of reclamation, along with the gas collection system, the humidification system is provided. The filtrate is pumped through the pump to the top of the cell, which is then distributed by gravity into the waste layers through perforated tubes. Perforated pipes have the shape of an umbrella and their laying is provided to the depth of 2.5 meters.

Installation of the III cell waste hydration system is provided during the operation. The perforated pipes for leachate recirculation will be arranged 2.5 m below the gas collecting system (see August report for details).

The precise parameters of pipe perforation: the diameter and quantity of the pipes are determined at the design stage.

The pumping stations are part of the leachate recirculation system, which transfer the infiltrate to the cells of the landfill and with their help the filtrate is recycled to the pumping station. The exact parameters are discussed in the corresponding section of the Conceptual Design.

Components of the landfill biogas utilization system

The components of the landfill biogas utilization system are:

- ✓ Compressor that provides the required working gas pressure for users;

- ✓ Gasholder, which provides the temporary accumulation and storage of landfill gases;
- ✓ System for cleaning the biogas from impurities;
- ✓ The burning Landfill gas by the Torch device;

The exact parameters for the equipment to be used will be determined during Design. At this stage, according to the measurements, it's recommended to install of the Torch device with the capacity of 2.5 thousand m^3/h. To produce such Torch, the initial pressure of 40 - 120 millibars should be created, which will be provided by compressor.

On the Fig. 11 show the scheme of the Torch device with the capacity of 2.5 thousand m^3/h.

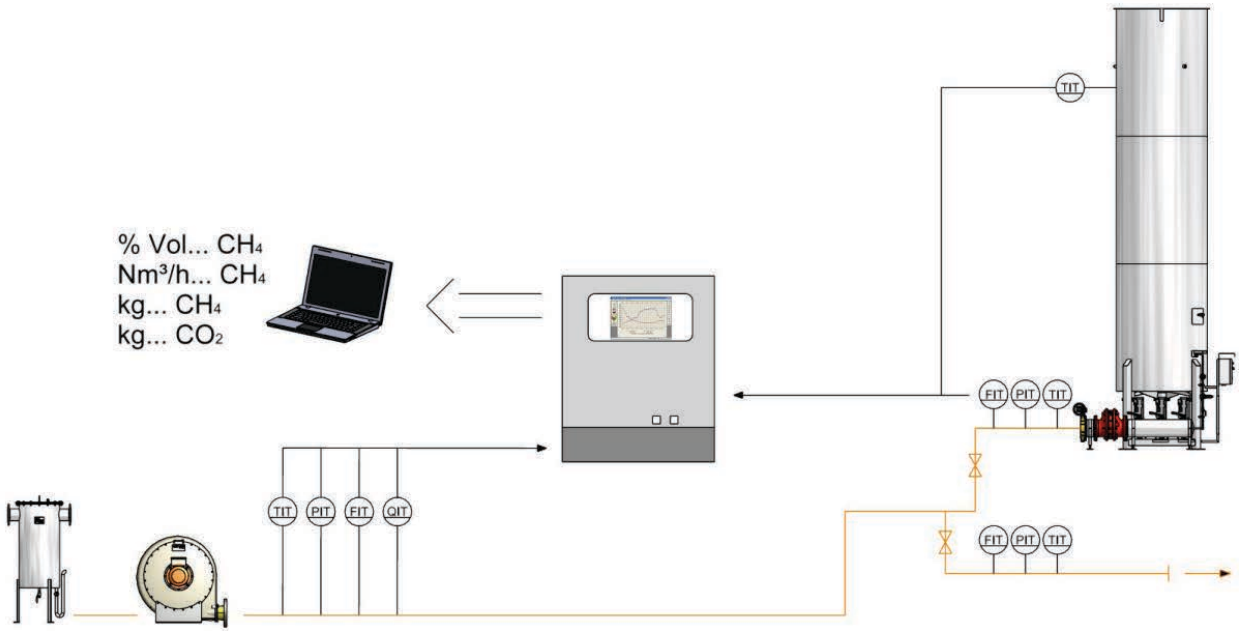


Fig. 11 The scheme of the Torch device with the capacity of 2.5 thousand m^3/h

According to studies, landfill gas composition is as follow: CH_4 (methane) - 51-54%, CO_2 (carbon dioxide) - 39,4-41,7%, O_2 (oxygen) - 0,4- 0,9%, N_2 (nitrogen) - 3,4-9,2%, H_2S (sulfur) - 380- 413 ppm, Co (cobalt) - 12,9-28 ppm, NH_3 (ammonia) - 193-200 ppm. In order to obtain the consumer quality of the biogas, it needs to be cleaned of carbon dioxide and sulfur. The cleaning methods and equipment are quite varied, so the final decision on the cleaning method and quality as well as the equipment to be used will be made at the design stage.

The future prospects for landfill biogas utilization

It should be noted, that the burning of landfill biogas from the financial and environmental point of view cannot be considered the most favorable approach. The burning of biogas results in the conversion of methane to carbon dioxide, with no additional benefits. At this time, there is only the reduction in the greenhouse effect of methane, but the use of energy by the Polygon operator is not observed.

Experts' assessment of the biogas potential on the Polygon shows that long-term use of biogas in co-generation facilities that can utilize its energy potential and generate heat and electricity is justified in the long run. The generated energy can be used to meet different needs during the operation of the landfill. For example, after the filtrate is purified by Reverse Osmosis, the use of biogas heat energy from the concentrate in the liquid evaporator or the source of electricity required for the operation of the Reverse Osmosis device itself.

The Work Volumes

The Vertical gas pipes:

- Collectors pipe - 5300 m;
- Pipes coming out of wells - 1664 m ;

Horizontal Gas Pipes:

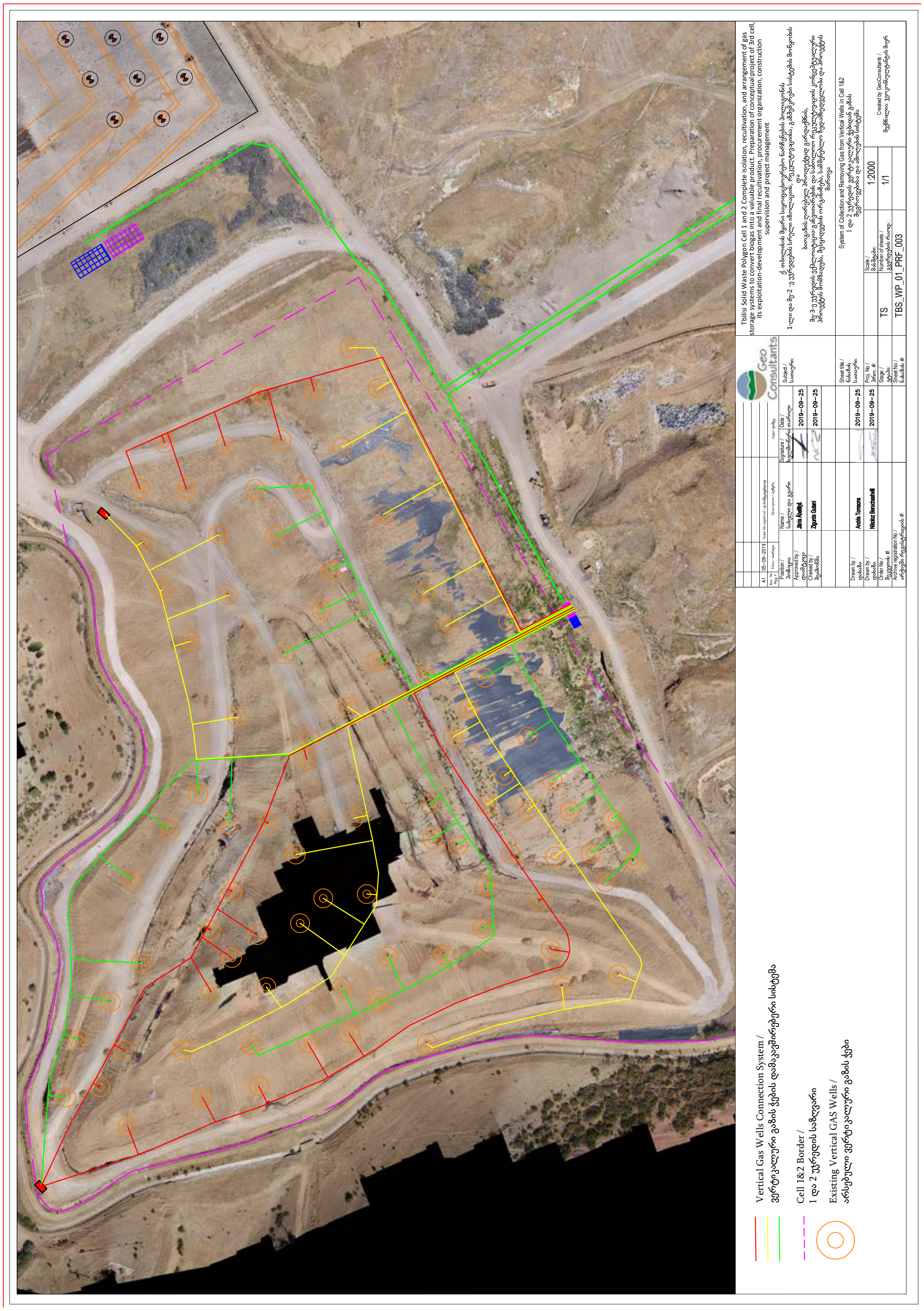
- Collectors pipe - 3400 m;
- Horizontal pipes - 4700 m;
- Pipes for condensate - 1250 m;
- 32 mm Pipes for condensate - 2500 m;

Water pipes:

- Water pipeline - 5600 m;
- Water collectors - 3750 m;

- Central gas pipeline for III cell- 850 m;
- Central gas pipeline for I-II cell - 540 m;
- Condensate holder - 8 units
- Land area - 195,000 m^2;
- Land capacity - 255,000 m^3;

Drawings


Vertical Gas Wells Connection System /
Cell 1&2 Border /
Existing Vertical GAS Wells /
Tbilisi Solid Waste Polygon Cell 1 and 2 Complete isolation, recultivation, and arrangement of gas storage systems to convert biogas into a valuable product. Preparation of conceptual project of 3rd cell, its exploitation-development and final recultivation, procurement organization, construction supervision and project management
System of Collection and Removing Gas from Vertical Wells in Cell 1&2
Geo Consultants
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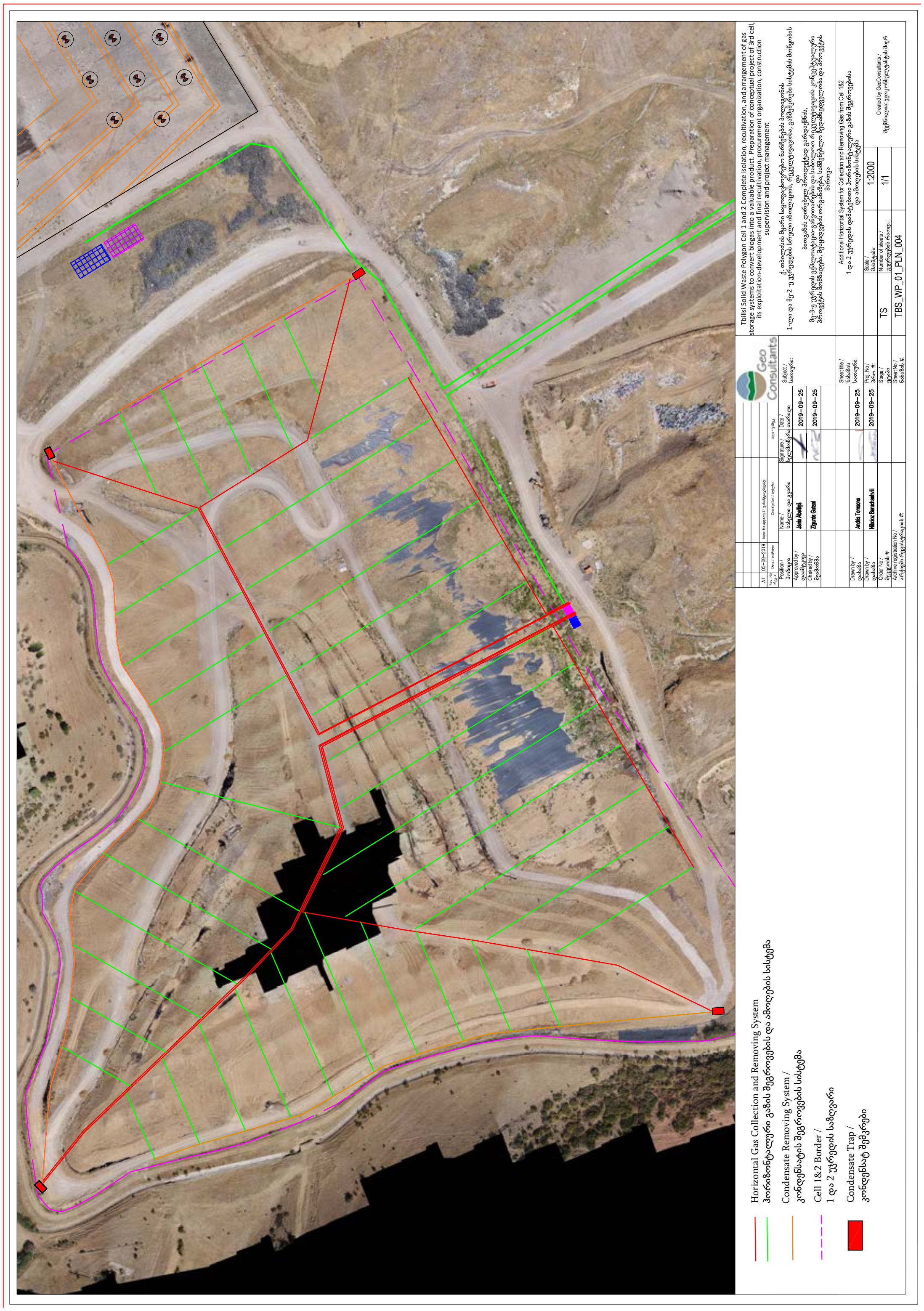
Tbilisi Solid Waste Polygon Cell 1 and 2 Complete isolation, recultivation, and arrangement of gas storage systems to convert biogas into a valuable product. Preparation of conceptual project of 3rd cell, its exploitation-development and final recultivation, procurement organization, construction supervision and project management
Additional Horizontal System for Collection and Removing Gas from Cell 1&2
A1
05-09-2019
Issue for approval
Approved by / Jānis Ābeltiņš 2019-09-25
Cheked by / Zigurds Gutāni 2019-09-25
Drawn by / Andris Tomsons 2019-09-25
Drawn by / Nikoloz Beruchashvili 2019-09-25
Scale / 1:2000
Number of sheets / 1/1
Stage / TS
Sheet No / TBS_WP_01_PLN_004
Created by GeoConsultants /
Geo Consultants
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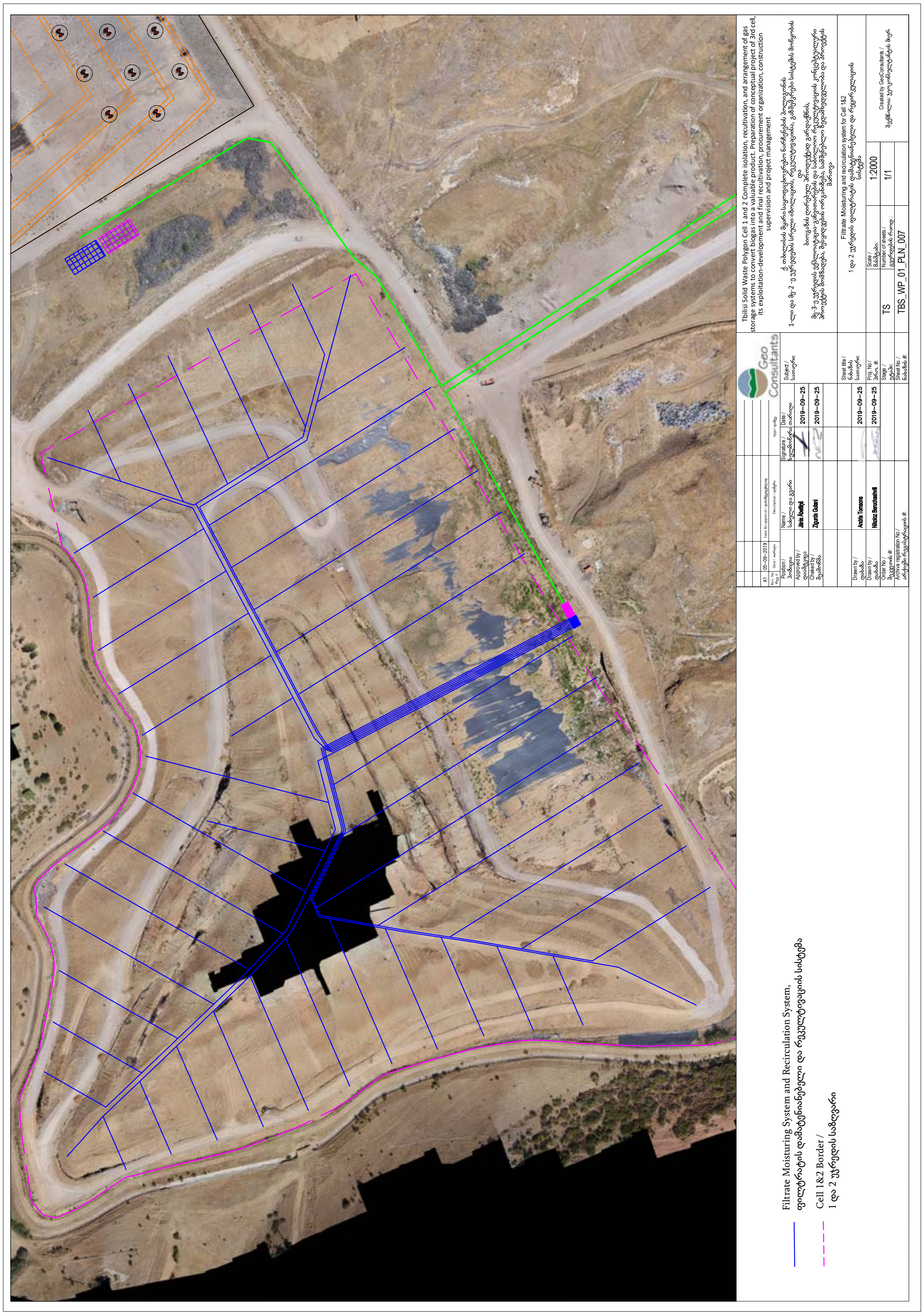
Condensate Removing System /
Cell 1&2 Border /
Condensate Trap /


Filtrate Moisturing System and Recirculation System,
Cell 1&2 Border /
Tbilisi Solid Waste Polygon Cell 1 and 2 Complete isolation, recultivation, and arrangement of gas storage systems to convert biogas into a valuable product. Preparation of conceptual project of 3rd cell, its exploitation-development and final recultivation, procurement organization, construction supervision and project management
Geo Consultants
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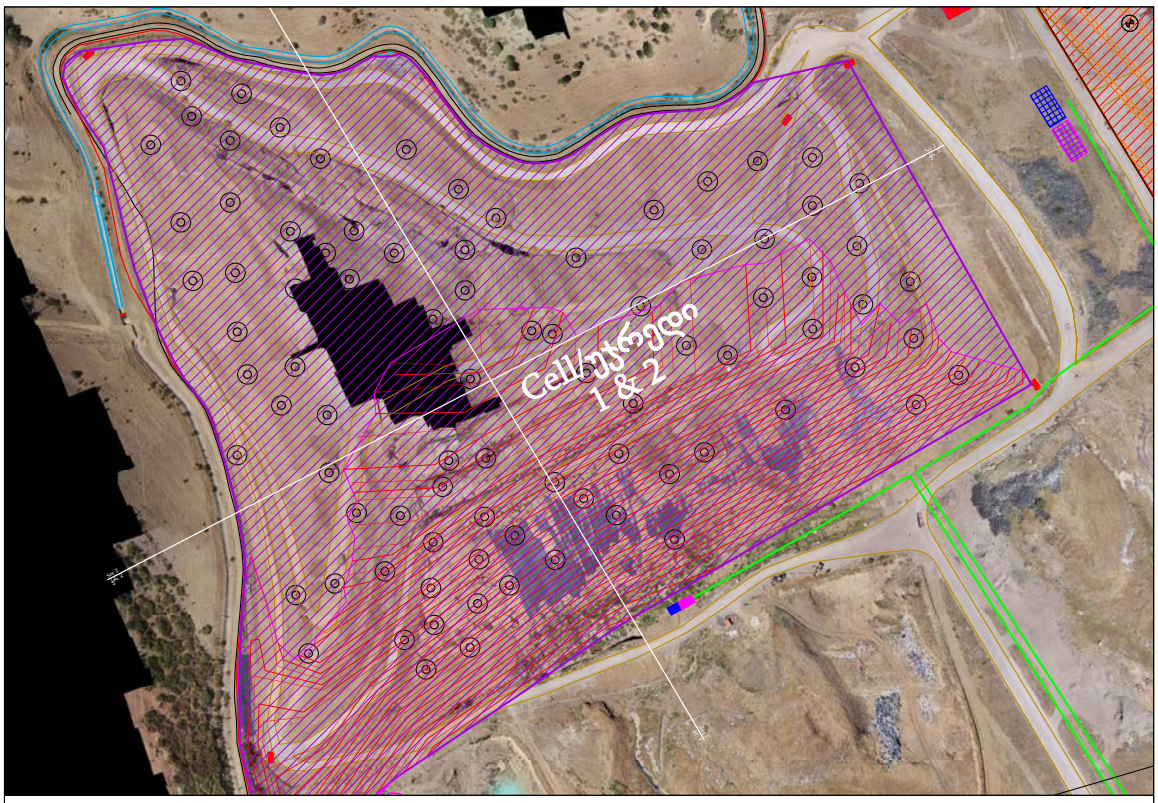
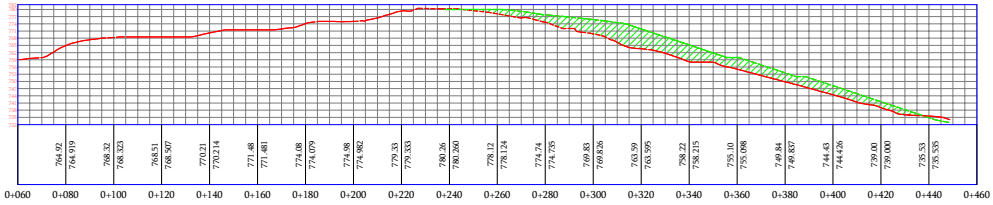


Section 1/ ჭრილი 1



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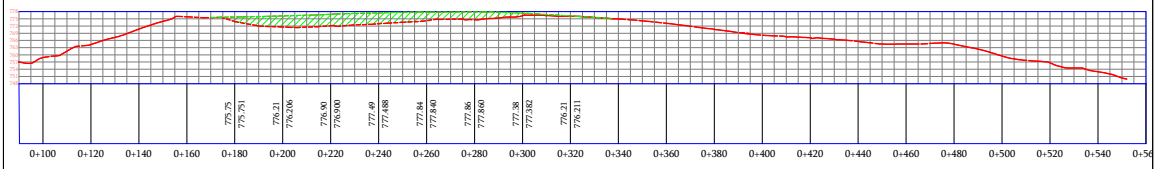
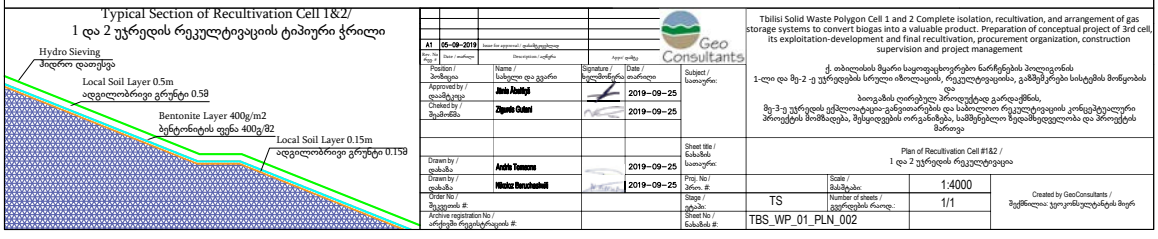




The III cell configuration, capacity, and operation

The implemented works on the III cell arrangement

In 2015, Gamma Consulting Ltd. developed Didi Lilo Polygon expansion project, which envisaged the construction of the III cell for further operation. They planned to arrange the III cell and place the waste from northeast to south.

Prior to the beagining of construction, was carried out preliminary works, in particular, the drainage systems were made along the entire perimeter in order to avoid sewage waters entering the cells (3-1 and 3-2) and the existing operating roads were lengthened.

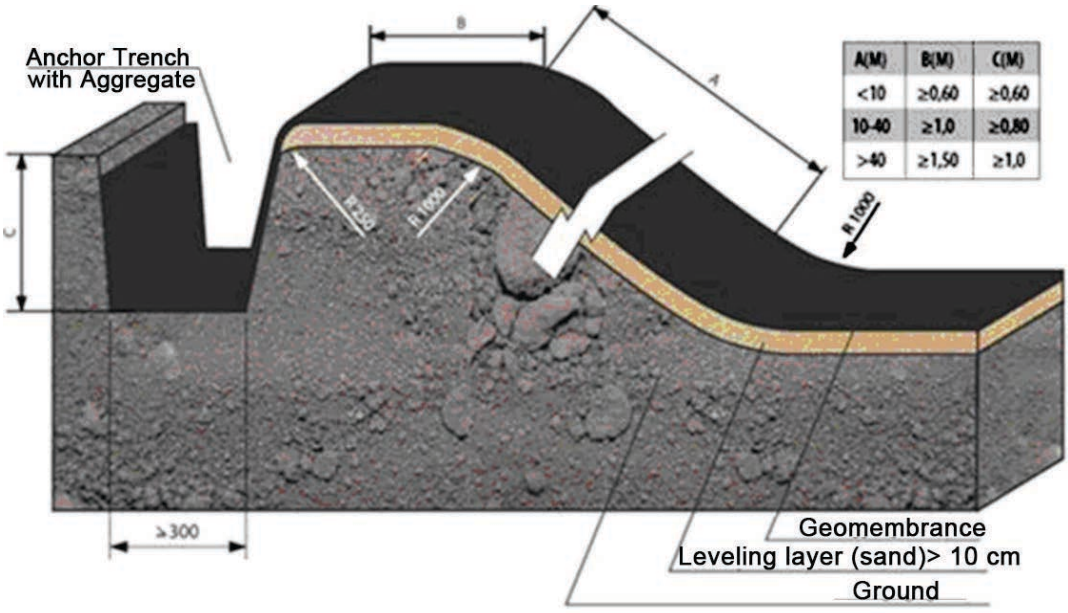


Fig. 12. The main nodes of the geomembrane pile, when forming the bottom of the cell

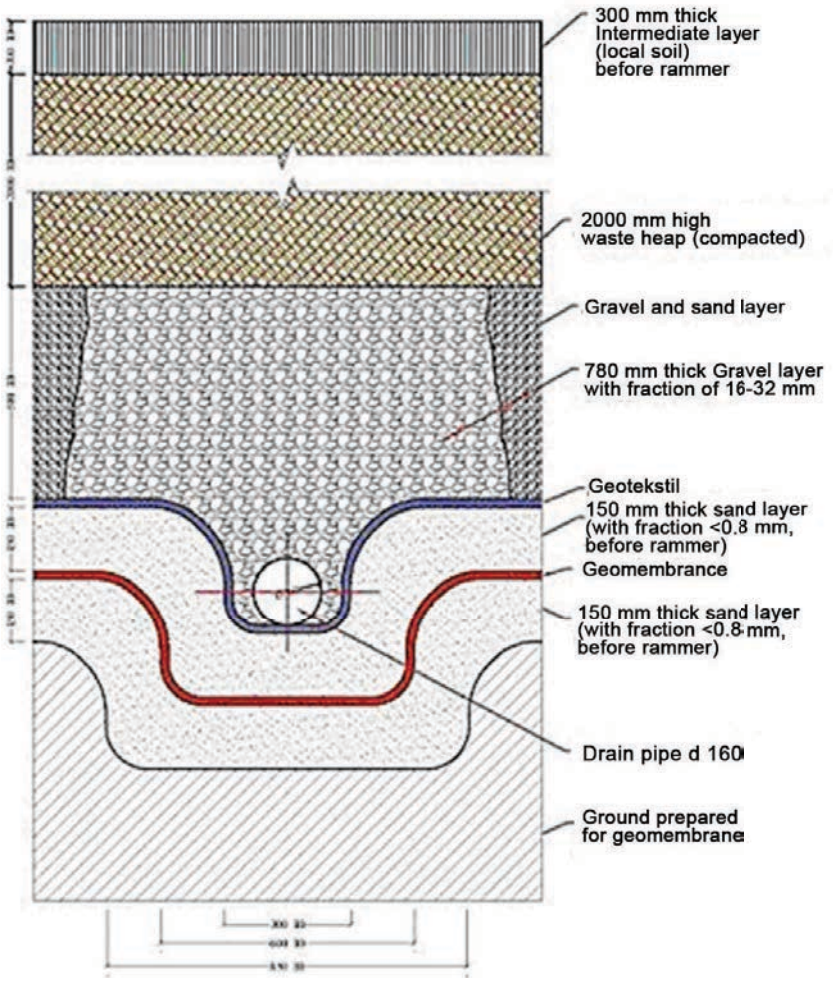


Fig 13. Constituent components the bottom of the cell

The builders worked the slopes and the bottom of the cave, built the drainage system (Fig. 12 and 13). The drainage system and collectors were made in the cell. 30 vertical gas gathering wells and temporary operational sites for unloading waste from garbage trucks were created.

Waste disposal at Didi Lilo Polygon in cell III was started in July 2019.

Existing project

- According to the existing construction project, the III cell consists of two parts (Fig. 14 and 15), the middle of which is filled and used for the moving vehicles. The III cell is in the process of being operated and filled in as follows:

- Initially, 3-1 part of the cell should be filled (on the left in the drawing);
- And then should be filled 3-2 (right) part of the cell.

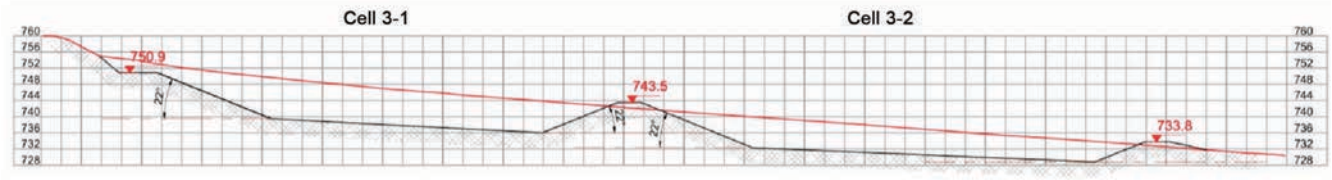


Fig. 14. The transverse section of the III cell

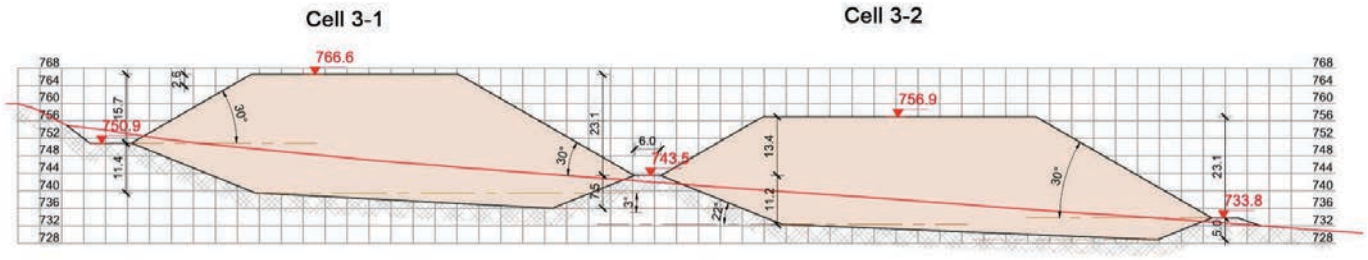


Fig. 15. The filled III cell transverse section

The calculated total capacity of the III cell is 685 338 m^3 wich divided as followe:

- The 3-1 part of Cell: 325 531 m^3;
- The 3-2 part of Cell: 359 807 m^3;

The slope of the filled cell to the horizontal line should be 30^0. The vertical filling of the chamber should be 2.3 m high, of which 2 m will be compacted waste and 0.3 m will be an intermediate layer from the clay and gravel. The material for the intermediate layer will be mined locally and during the construction of the III cell will be sotred nearby.

To carry out work within the framework of the current project, Geo-Consultants Ltd from August 9-11, 2019 conducted field work at Didi Lilo Polygon and compose the new ortho plan. The results are shown in Appendix 2.

Recommendations for changing III cell configuration and existing operating practices

According to the existing Design, the III cell is located on the sloping surface and after its filling the maximum design height at the top of the slope will be 15.7 meters (750.9m above sea level), in the middle of the slope will be 23.1 m (743.5 m above sea level) , and 23.1m at the bottom (733.8 m above sea level). To change the cell configuration and capacity, by the consultant were recommended that:

1. Increase the capacity of the cells:
    - Increase the maximum design height by 4.7 meters (from 750.9 m to 771.3 m);;
    - Increase cell height at the bottom of the incline by 14.4 meters (from 733.8 m to 771.3 m);
    - Integration of the two parts (3-1 and 3-2) of the III cell at the expense of filling the space between the first and second parts.

2. To ensure the stability of the slope of the cell, it is recommended to reduce the risk of erosion caused by water and slope treatment with the compactor, which will reduce the angle of inclination to V: H = 1: 3. This slope mark is obtained from the document - EU Waste Governance - ENPI East, approved in October 2010 7.9.2. Landfill Operation Manual;

3. In order to improve the stability of the cell slopes, it is necessary to provide conditions for the effective operation of the equipment while performing cell reclamation and erosion woks. It's also important, that during the construction of the gas-collecting and leachate collecting systems, should be arranged terraces with the height of 7.5 m and the width of 3 m. That also recommended by the document 7.9.2. Landfill Operations with Guidance Manuel;

4. Cell formation should be carried out with 2.5 m high waste layers;

5. Sequence of cell formation see in the Fig. 16;
    a) 3-1 part of the cell up to mark 756.3, with the capacity of - 229 279.22 m^3;
    b) The 3-2 part of the cell joins the 3-1 part to the 756.3 mark with the capacity of 401 005.66 $м^3$;
    c) Formation of 3-3 parts of the cell takes place from the mark 756.3 to 771.3, the capacity of which is 212 123.16 m^3.

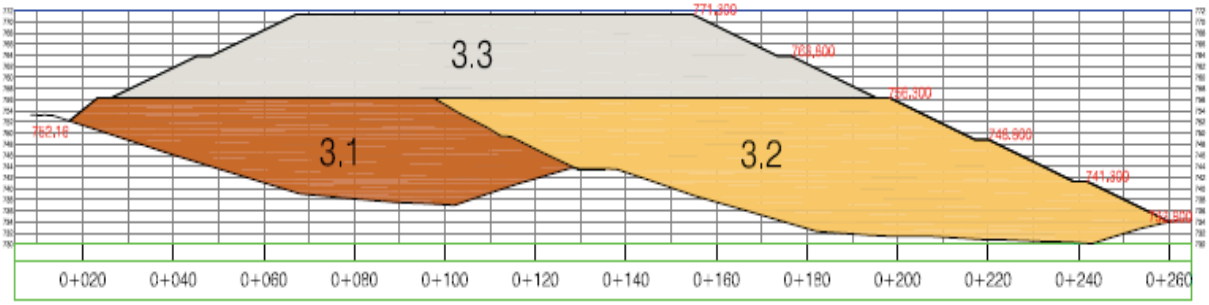


Fig. 16. The transverse section of the filled III cell with modifications

Changing the III cell configuration by the scheme proposed by the expert will increase the capacity of the cell to **842 408.04** m^3. If the amount of waste deposited on the Polygon per year is 380 330 t and its compaction is 0.7 t / m^3 (380 330 / 0.7 = 543 328.57 m^3), then the cell's life span will be 3 months longer, than the projected capacity. In addition the overall duration of the operation will increase from 15 months to 19 months.

With the use of the TANA firm compactor it can be compacted up to 0.9-1.0 t / m^3 of the waste. This will extend the life of the cell up to 27 months.

Placement of the waste in the cells and the layers forming

According to the Landfill Operations Guidance Manual, published in October 2010 by the EU Waste Governance - ENPI East p.7.7.1.1 "it is recommended that most operators adopt the "face tipping" method for waste discharge and emplacement. This cell surface covering method has the following advantages:

- ✓ Machine operators find this method easy;
- ✓ It is easy to apply daily cover;
- ✓ Temporary access roads can be provided easily;

- ✓ Bulky objects are easy to bury; and
- ✓ Problem wastes can be tipped at the bottom.

By the above mentioned method, cell formation with 2.5 m layers of waste is advisable, and in the process of layer formation, the layer compaction should be top-down. During the formation of the terraced slopes, after every 3 layers, the vertical terrace will be completed with the recommended height of 7.5 meters and an optimal width of 3 meters. Considering the fact, that the annual amount of waste on the Polygon is 380 379.70 t, then the average daily waste is 380 379.70 / 365 = 1042 t. When the waste is compacted at the rate of 0.7 t / m^3, the daily waste volume in the cell will be 1042/0.7=1489 m^3.

The compactor manufacturer (TANA) provides recommendations on the optimum slope of the work surface V: H = 1:10 - 1: 6. Therefore, we consider that in our case this is equal to 1: 6 and the horizontal layer is 2.5 meters thick. The area required for unloading from the garbage truck should be at least 10 meters. The section of the active zone is given on Fig. 17. It's desirable that the optimum thickness of the waste that the compressor should compress each time, does not exceed 0.3-0.5 m. It should be selected depending on the equipment – accordint the weight of the compressor. Accordint of the 7.5 p. of Landfill Operations Guidance Manuel, the 0.5 meters is considered to be the optimum thickness of the waste for the compactor, otherwise the waste may be compacted incorrectly from the top of the compactor.

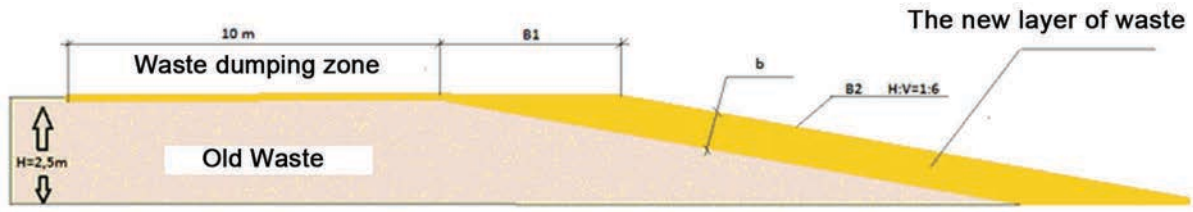


Fig. 17. The transverse section of the active zone of Polygon

The area of the active zone of the cell depends on the thickness of the waste deposited and processed on the cell layers. The data are presented in Table 1:

Table 1. Active Cell Parameters of the Polygon

Slope inclination V:H	Non-compacted waste layer thickness - b, m	B1, m	B2, m	Waste dumping zone m	Width of the active zone m	Active zone area m^2
1:6	0,7	4,2	15,2	10,0	139,9	2714

1:6	1,0	6,1	15,2	10,0	98,0	2087
1:6	1,5	9,1	15,2	10,0	65,3	1587

On the Fig. 17 shown the width of the new layers of waste in the cell - b, which is not equal to the height of the created layer, since after compaction of the waste, its height is determined perpendicular to the surface, and these two values differ from each other. As we have already mentioned, the optimum thickness of the new waste is 0.3-0.5 m. During the working day, the waste should be placed on the same site, until the planned daily increase will be achieved, taking into account the direction (see Fig. 18).

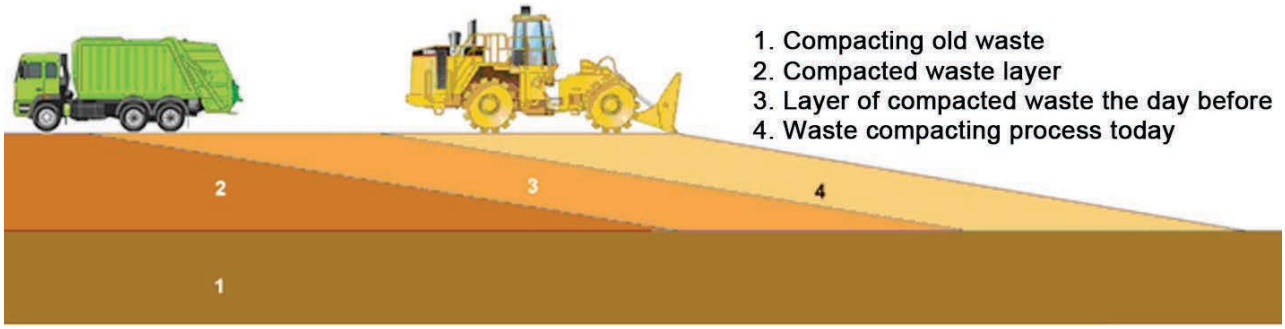
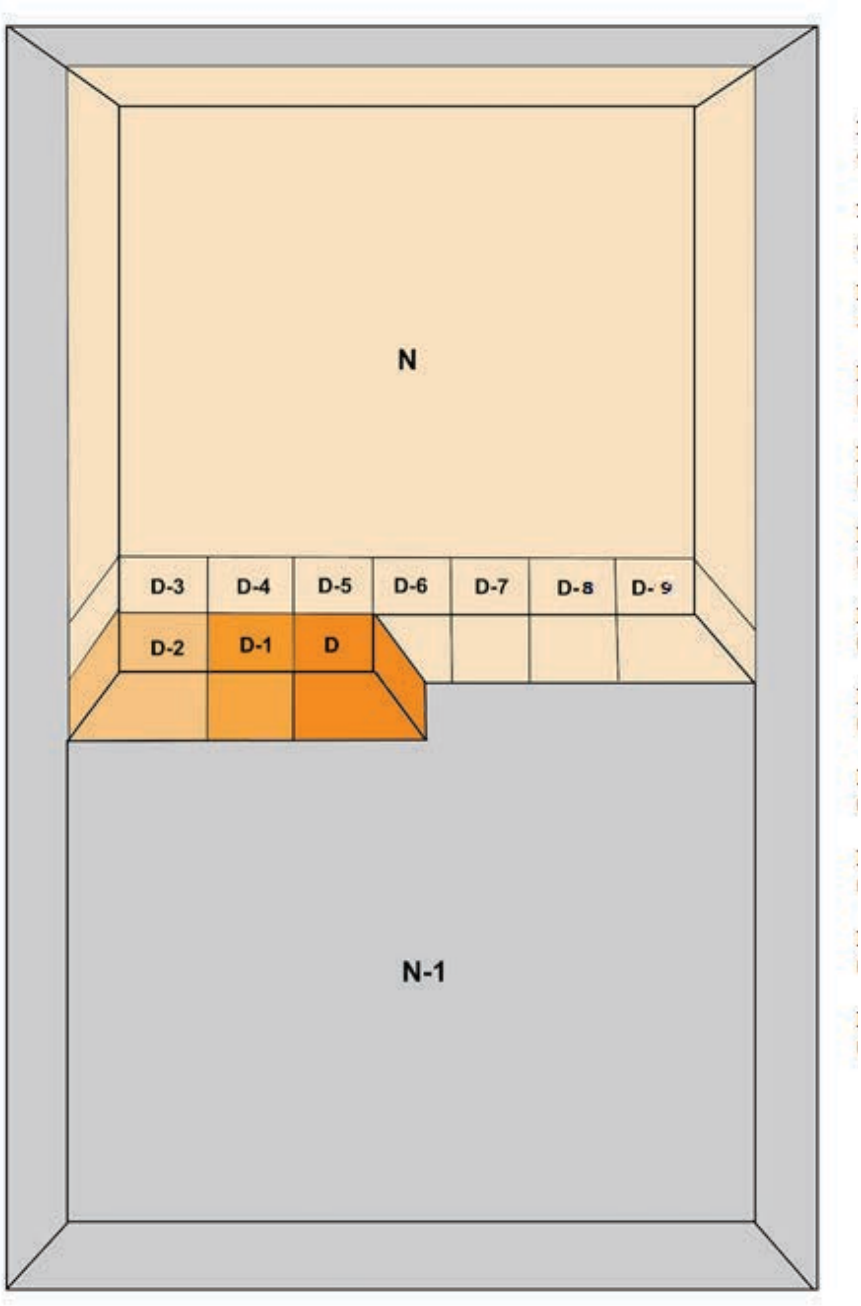


Fig. 18. Formation of waste layers on the Polygon

In 2013, the document was adopted - "Waste Disposal on the Landfill" #1999/31/EC[1] Landfill Gas Control – Guidance on the landfill gas control requirements of the Landfill Directive. The guide states that the active Polygon waste disposal site should have the possible minimum open area. Therefore, the active zone of the landfill should be designed with the minimum area necessary for dropping waste from the garbage truck and the free movement of heavy equipment - the compactor on the active zone.

It's best to start replenishing the cell with one of its most optimal edges and to place new pieces of waste daily in the transverse direction to the other end of the cell. The formation of new layers of waste in the cell by the given scheme shown on the Fig. 19.

[1] Comply with Georgian legislation: Resolution of the Government of Georgia #421, On Approval of technical regulation "On the construction, operation, closure and after-care of landfills;



N - Zone of formation of waste layers

N-1 - Compacted layer of old waste

D - Waste disposal active area

D-1 - The day before compacted waste

D-2 - Two days before compacted waste

D-3 - Tree days before compacted waste

D-4 – Four days before compacted waste

D-5 – Five days before compacted waste

D-6 – Six days before compacted waste

D-7 – Seven days before compacted waste

D-8 – Eight days before compacted waste

D-9 – Nine days before compacted waste

Fig. 19. Formation of new layers of the waste in the cell

Environmental Impact Assessment and Risks of the Polygon

Disposal of waste at the landfills is the most common waste management practice in Georgia. Its environmental impact is so significant, that permitting the construction of the landfill, along with other technical documentation required for construction, involves

developing the scoping, screening and Enviromental Impact Assesment document. Based on this document, the Ministry of Environment and Agriculture of Georgia issues the consent for the construction of the facility under relevant permit conditions, the compliance with which is mandatory during the operation, closure and post-closure phase of the landfill and is strictly controlled by the Environmental Supervision Service.

The following environmental and technical parameters are under special control when managing the Polygon:

- ✓ Surface waters, groundwaters and landfill leachate;
- ✓ Landfill gas emissions;
- ✓ Unpleasant odor and dust particles;
- ✓ Noise caused by heavy machinery work;
- ✓ Light fractions of the waste, fluttering in the wind;
- ✓ Birds, rodents and insects;
- ✓ Fire caused by methane ignition;
- ✓ Drainage systems;
- ✓ Stability of waste mass on disposed on the Landfill;
- ✓ Ground erosion.

Environmental impacts of the Landfill, its causes and necessary mitigation measures

Risks associated with the management of landfills, their causes and the necessary mitigation measures are shown in the Table 2.

Table 2. Risks associated with the management of landfills, their causes and the necessary mitigation measures

Risk factors	Causes	Mitigation measures
Spreading unpleasant odors	Landfill gases, leachate	Landfill gas collection through the horizontal gas collection system; Maximum reduction area of active surface of the cell during operation;

		The proper functioning of the leachate treatment system.
Noise caused by moving machinery and garbage trucks	Operation process	Optimization of heavy machinery and garbage trucks routes
Light fractions of the waste fluttering in the wind	The presence of light fractions in the mixed waste, which is difficult to compact, and the ability to adhere to the ground is very low	Waste isolation with overlap characterized by: • Good adhesion to the top of the waste; • Low water penetration ability; • Low penetration of the gas emissions; • Minimize access animal and bird to the waste; • Use additives to fight against the spread of insects; • Protection slopes of the cell against the erosion.
Dissemination of birds, rodents and insects in the landfill	Disposal of such waste in the landfill - which attracts birds and promotes the spread of insects	
The appearance of large amounts of leachate and possible pollution of surface and groundwater.	High permeability of precipitation from the landfill surface and atmospheric precipitation penetration into the landfill	
Fire	Ability the landfill gases to ignite and penetrate air into the landfill body, Putting easily-flammable fractions in landfill and ignoring fire safety standards.	Observance of fire safety norms on the Polygon; Moisture using leachate recirculation system.
Downfall and erosion of the Polygon slopes	Diverse structure of landfill body, non-uniform hydration, non-compliance with permissible cell slope thresholds	Ensure equal alignment of the recirculated infiltrate in the body of the Polygon; Provide necessary tilt of the cell slopes; Slope erosion protection.

Reducing the above risk factors and taking the necessary measures to mitigate them for the proper functioning of the landfill is an important problem underlying the EIA document. Didi Lilo landfill has received an EIA document in 2010, which is currently being

updated and is in the process of adapting to the adopted legislation. The mitigation measures indicated in Table 2 imply the proper functioning of the processes and systems necessary for the operation of the Landfill. This means that one mitigation measure affects several risk factors at the same time and several measures simultaneously serve to enhance the effect of each of them. Given this, there is the synergy of technologies that serve to minimize adverse effects on the environment and human health during the operation of the Polygon. The measures to consider when operating the Polygon are:

1. Horizontal collection of landfill gas in parallel with active operation;
2. Effective hydration of the waste by the means of leachate recycling system;
3. Systematic intermediate overlap of the compacted waste on the active cell surface to protect against precipitation and wind exposure;
4. Correct geometrical configuration of the upper part of the landfill;
5. Procedural change of operation to reduce the area of active cell surface;

The above measures will be discussed in more detail in the following chapters of this document, except of the measure 4 – "Correct geometrical configuration of the upper part of the landfill" - which will be presented in the Volume 2 of the current report.

Landfill gas horizontal collection system

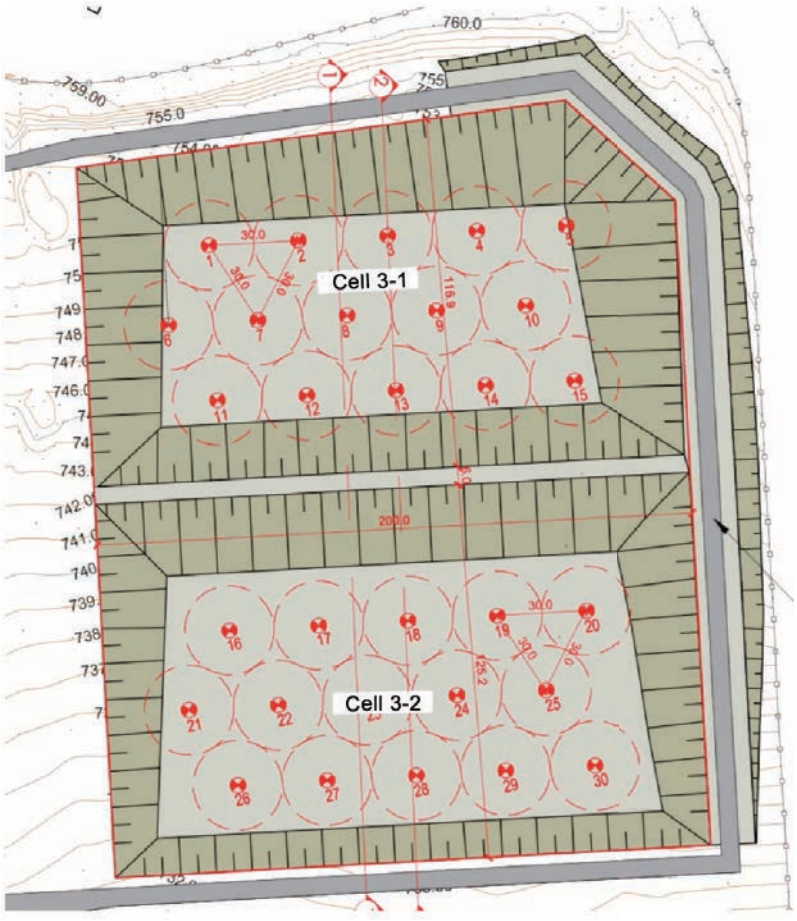


Fig. 20. Vertical gas collecting wells mounted on the III cell under the existing project

To reduce unpleasant odors, toxic gases and their greenhouse effect, during the operation of the landfill in the adjacent area, in accordence of the "Landfill Gas Control – Guidance on the landfill gas control requirements of the Landfill" Directive - It's recommended to start the collection of gases from the active cell of the landfill in the early phase of mini-operation. According to the construction project of the III cell of Didi Lilo Polygon, there are installed 30 vertical wells (see Fig. 20). Interconnection with vertical gas collectors and subsequently coupling to the central collector and compressor system will be possible, only after the final filling of the III cell.

The generation of landfill gases is the process, followed by the decomposition (anaerobic degradation) of the fraction of the organic substancies present in the waste, which begins 2.5–4 months after the start of waste disposal on the cell. The generation of landfill

gases is the process dependent on temperature (season) and humidity. Which means, that as the air temperature rises, biomass degradation and emissions become more intense. The III cell filling time in 2.2.1 was was determined 19[2] months. Therefore, the vertical gas collecting system, mounted on the cell cannot be operated until this time and air pollution will be occur throughout the cell's operation period.

Rijeka, Croatia, on the Mariscinas - Polygon (2019)

There was Didi Lilo Polygon's similar case of the operation in Rijeka, Croatia, on the Mariscinas – Polygon. After 1.5 years of organic waste disposal on the Polygon, the intensive anaerobic degradation began, followed by the release of large quantities of gases (biogas). The reason for this uncontrolled process was the neglect of the gas collection and temporary covering of waste during operation, which could prevent the ingress of large amounts of precipitation in the waste. As the result, the moisture of the waste reached 60-80%, which made the anaerobic decomposition process considerably more intensive. In 2018, residents of the settlements adjacent to the Polygon expressed indignation for unpleasant odor, which forced the new leadership to carry out the following actions:

- *At each gas collecting well were installed activated charcoal filters;*
- *The surface of the waste is overlaid with HDPE membrane;*
- *Then overlapped by 0.5 m - 1 m thick clayey soil;*
- *The area of active surface of the cell was maximally reduced.*

Despite the work done in May 2019, unpleasant odors again began to spread from the Polygon. The reason for this was that the emitted gases greatly increased the pressure inside the cell and the gases began to escape from different places (cracks) of the cell in addition to gas collection wells. To solve this problem, the Polygon manager decided to install special valves in gas collecting wells, from which additional gases was pumped out and then burned.

The correction of the errors was so costly that the decision to install the ***Horizontal gas collecting system*** *was made, during the subsequent operation of the cell.*

To avoid the uncontrolled gas emissions from III cell of the Landfill and minimize unpleasant odors, in parallel with the operation, it's recommended to degassify through the

[2] With the use of the TANA firm compactor it can be compacted up to 0.9-1.0 t / m^3 of the waste. This will extend the life of the cell up to 27 months.

horizontal gas collecting system, and after the cell is operated, additional gases will be collected from the vertical gas collecting well and will be used afterwards.

Horizontal degasation system

The horizontal degassing system is the 100 mm diameter plastic pipe with open end that sticks out from the inclined surface of the cell. The part of the pipe that enters the cell is perforated in 3 meters from the open end, that allow collect the gases.

The pipes are laid in the 0.5X0.5 m trenches, which are excavated on the surface of the formed compacted waste. The trench is filled with the 20-40 or 40-70 cm gravel. Geotextiles with the width of 1 m are used to cover the trenches, which prevents the diffusion of leachate from the upper layers of waste and clogging of the perforated part of the pipes.

The open ends of the pipes are connected to the cololectors, eventually connecting to other components of the degassing system. The schematic representation of the horizontal degassing system is shown on Fig. 21.

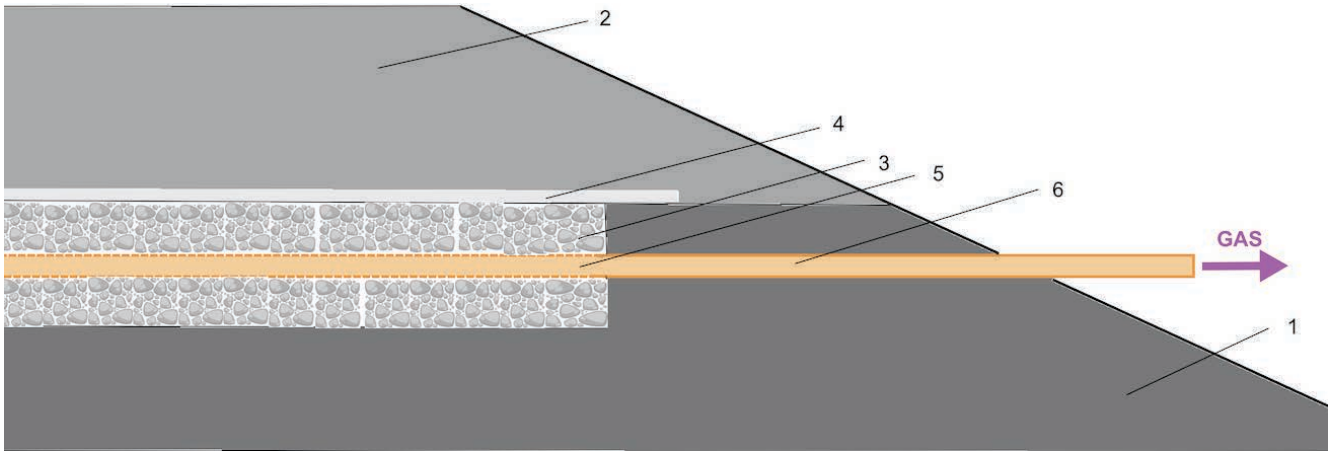


Fig. 21. Horizontal Degassing System: 1- Lower layer of compacted waste; 2- Top layer of compacted waste; 3 - The trench filled with gravel 4 - Geotextile; 5 - Perforated part of the pipe; 6 - Unperforated part of the pipe, with open end that sticks out from the inclined surface of the cell.

The optimum distance between the degasation channels is 15 meters on the horizontal and 7.5 meters on the vertical (pipes pass through every third layer of waste).

Each new layer is laid in the checkerboard pattern, halfway (7.5 m) from the horizontal (Fig. 22).

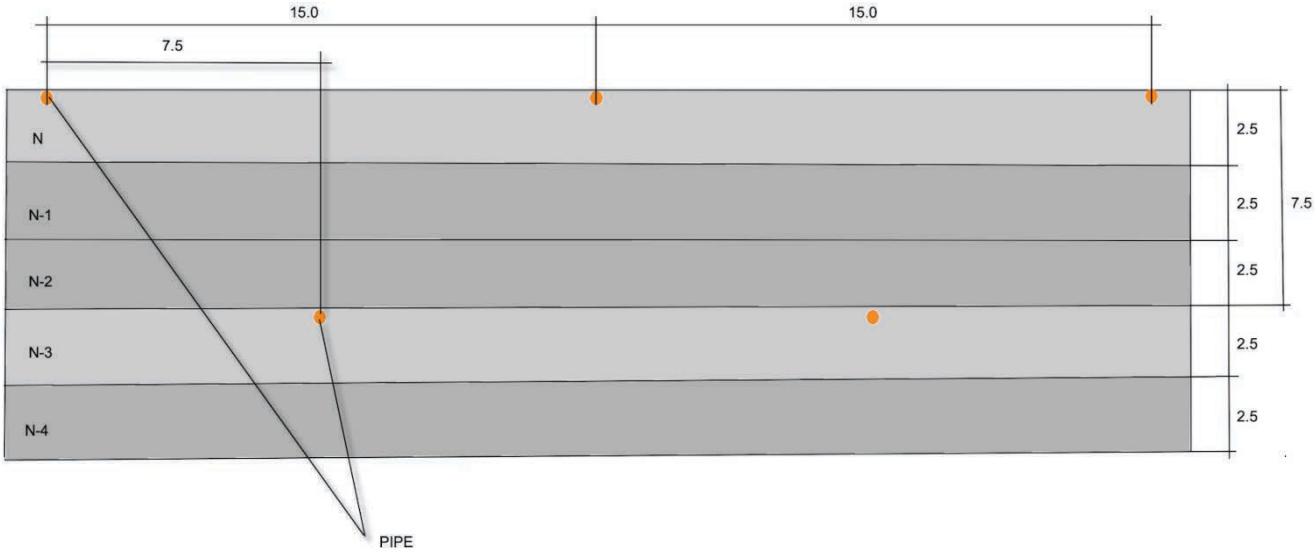


Fig. 22. Vertical section of degasation channels; N- N-4 Formed layers of waste in sequential order

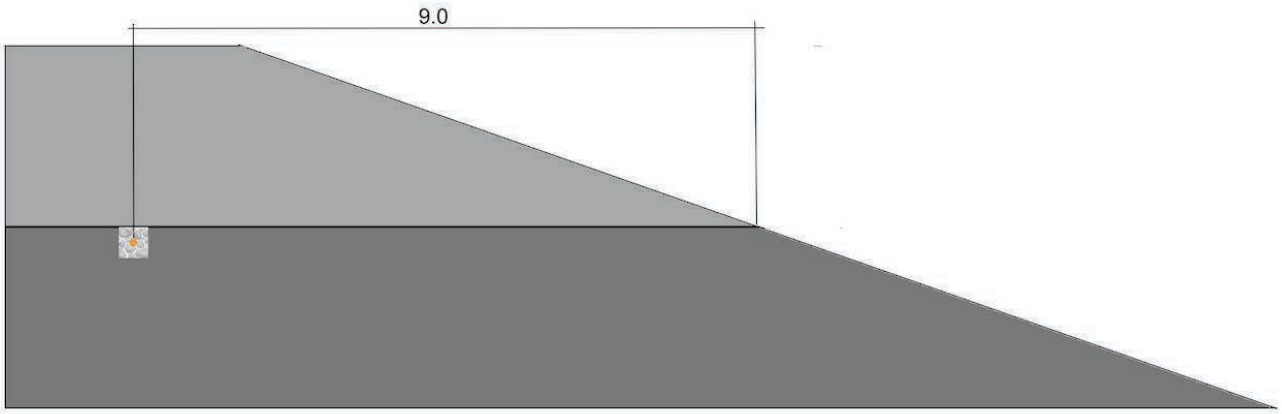


Fig. 23. Minimum distance horizontally from the degassing channel to the inclined surface of the cell

Degasation channels are drawn in parallel. Minimum distance from horizontal degassing channel to the inclined cell surface is - 9 meters (Fig. 23).

Installation of the degassing system on the active cell of the landfill

Horizontal degasation system should be installed in parallel with waste disposal on the III cell. The surface treatment of the compacted waste (doing trenches) at the specified height and the pipe laying should be done in accordance with the parameters described in section 3.1.1.1. It's important, that during the degasation installation works, no other construction-installation works should be performed on the Polygon and no heavy machinery should be moved. In particular, first necessary to start laying vertical gas collection pipes and then start the works related to the horizontal gas collection system. After the construction of the channel is completed, it should be covered with the layer of geotextile and the ballast layer should be applied to fix it. The top of the ballast layer on the surface of the Polygon should be coated with the intermediate insulating material. The horizontal channels should be designed on the Polygon so, that they shouldn't cross the vertical gas collection wells and pass as far as possible between them.

Effective hydration of waste through the leachate recycling system

Optimal hydration (hydrolysis) of waste placed on landfills is important not only in terms of fire safety standards, but also one of the contributing factors to intensification of anaerobic processes on the Polygon. Landfill gases resulting from anaerobic decomposition of the organic waste - biogas, whose value-added component is methane, is the renewable energy source for Polygon operators. If used optimally, the cost of the basic energy needs to operate the landfill will be significantly reduced.

Infiltrate Recycling System

The principle of arrangement of the leachate recirculation system is similar to the horizontal cell degasation system. The same can be said about the perforated pipe system located horizontally in the inner layers of the cell, except that if the air is pumped out during degassing, then the infiltrate is pumped into the recirculation system using the pump. The optimal location of its pipes in the Polygon cell is under those layers of waste, where the degassing pipe system is laid (Fig. 24).

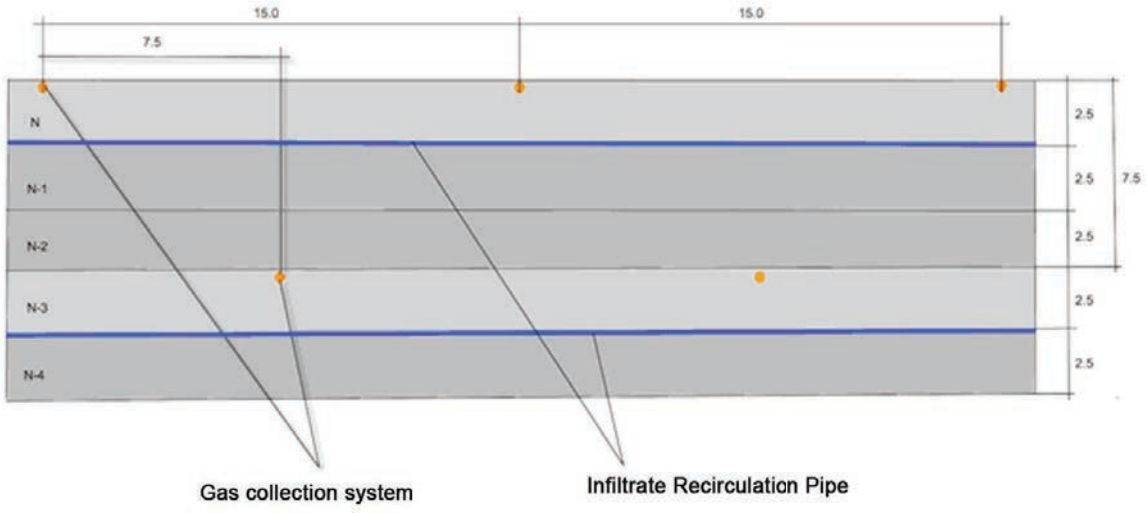


Fig. 24. Relative location of the gas collection pipes and leachate recirculation system

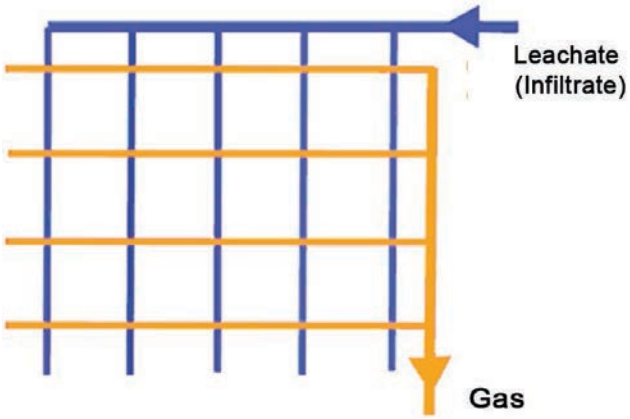


Fig. 25. The scheme of the relative location of the gas collection pipes and leachate recirculation system

In order to avoid the excessive leachate into the degasation system, it is advisable to lay the pipes in the leachate recirculation system perpendicular to the degasation system. (Fig. 25), however, depending on the Landfill configuration, the parallel pipe-laying systems is also possible. Detailed drawings of the relative location of the leachate recirculation system for the waste hydration and the horizontal gas collection sistem pipes in the III cell of Didi Lilo Landfill, you can see in the attached files.

Installation of the leachate recycling system on the Polygon and hydration of waste

Installation of the horizontal degassing pipes in the III cell is carried out in parallel with waste disposal. Similarly, the pipes of the leachate recirculation system are laid in the channel on the surface of the formed waste layer, on the upper layer of which the pipes of the degassing system are already laid in accordance with the parameters described in section 3.1.1.1. It's important, that during the de-gasation installation works, no other construction-installation works should be performed on the Polygon and no heavy machinery should be moved. In particular, vertical gas collection pipes should already be installed on the cell.

After the construction of the channel is completed, it should be covered with the layer of geotextile and the ballast layer should be applied to fix it. The top of the ballast layer on the surface of the Polygon should be coated with the intermediate insulating material. The horizontal channels should be designed on the Polygon so, that they shouldn't cross the vertical gas collection wells and pass as far as possible between them.

Intermediate covering used for insulating the waste layers during operation of the Polygon

In the legislative framework in the Chapter 1, Resolution of the Government of Georgia #421, On Approval of technical regulation "On the construction, operation, closure and after-care of landfills" sets out the technical requirements, measures, and procedures for preventing or eliminating the adverse environmental impacts of landfill and ambient air during the full life cycle of the Polygon operation.

In accordance with p. 35 (c) of Regulation #421 - The landfill should be daily covered with the layer of soil and/or daily, intermediate and long-term used alternative household waste (suspension, consisting of synthetic and fibrous polymeric material, cellulose fibers), at the temperature of + 5^{0}C , or higher, and in conditions of air temperature below + 5˚C - at least once every 3 days.

The intermediate coverings used to isolate the waste layers at the landfill can be the different types, however, they must necessarily meet the following requirements:

- Minimizing the spread of the unpleasant odors by the landfill gas emissions;
- Ensure anaerobic conditions at the waste disposal site;

- Prevention of the air entering in the waste layers;
- Minimizing the Light fractions of the waste fluttering in the wind;
- Prevention of attraction and propagation of the birds, rodents and insects on the Polygon;
- Landfill fire prevention;
- Stabilization of waste mass on the Polygon and prevention of cell slippage.

The friable intermediate covering

The most widespread traditional method of waste insulation is covering. Its main advantage is the widespread availability and easy access to the heavy machinery, necessary for work, since the heavy machinery necessary for the operation of the Landfill - bulldozer, the front-end loader, is also used for the laying soil on the surface of the compacted waste layer.

Soil and other inert materials have the number disadvantages, mainly due to the large area occupied in the cell of the Polygon and, as the result, the shortening of the life cycle of the Polygon. During the Polygon covering, the optimal gas ecstraction and leakage of the optimum water level in the residue layers to prevent the erosion of the cell surface, depends on the composition of the friable intermediate layer.Given this, during the operation of the landfill, the most difficult task is and it's almost impossible to predict the effectiveness of the covering with friable material and standardize the procedures for its use.

The soil, used for daily layering of the compacted waste on Didi Lilo Landfill has the high clay content, which complicates the efficient gas extraction and prevents the leachate from evenly distributing in the cell of the body during recycling.

Alternate Intermediate Cover

With the development of technology, there has been the great deal of experience in the world of using different types of coverings and inert coverings as the alternative. In the ASTM D6523 standard - "Standard Guide for Evaluation and Selection of Alternative Daily Covers (ADCs) for Sanitary Landfills" – is discussed and compared with each other alternative intermediate covering for different types of Polygons. Table 3 shows the following alternative and friable intermediate coverings:

- Foams;
- Sprayable overlapping mixtures;
- Reusable Geosynthetic overlay;
- Disposable geosynthetic overlay;
- Friable inert materials.

Table 3. Tested materials of intermediate coverings and their use on the landfill

Properties of the covering material and ways of use	Foams	Sprayable overlapping materials	Reusable geosynthetic materials	Disposable geosynthetic materials	Friable intermediate cover
Overlay method	Self-moving/ towed device that dispenses foam with the collector or is mounted on the truck and is manually distributed using the special hose.	Liquid spray mounted on the trucks or trailers (identical to water spray).	Laying geosynthetic material manually, using the compactor, or special equipment that expands and collapses large rolls of covering material.	Manually or using the special device mounted on the bulldozer or compactor. Ballast soil lies on the top.	Basically, like soil, covered by the bulldozer.
The technical conditions after coating:					
a) It's imperative to clean or maintain the equipment	High	Low	Low, if covered by appliances.	Low, if covered by appliances.	Low
b) Removing the cover	No need	No need	Requires	No need	No need
Covering in the different climates					

a) Rain	Some types of foam are not recommended for use in the rain, although some withstand low or medium rainfall.	With light rain, dispose can be made, and after polymerization it withstand low or medium rainfall.	The use of some types of materials has no limitation, while some when become wet, make the dispose process more difficult.	Rain helps to stick the material to the surface.	There is generally no restriction but some inert materials are rinsed off.
b) wind	Can be used in winds of 9 to 18 m/s. Adheres the surface strongly.	In most cases it can be used in winds of up to 21 m/s.	Depending on what type of ballast is used. Wind can damage the material used for covering.	Needed to use more ballast. Smaller material is less damaging.	Applicable to most types. However, on sweeped streets and car wastes, the wind affects significantly.
c) Frost, snow	It can be used during frost, but the device should be adapted to frost conditions.	It can be used during frost and snow.	The some materials have limitations. Materials that absorb the water during freezing make it difficult to overlap / remove.	Requires the use of the ballast that does not contain water and does not freeze e.g. broken glass.	There are no difficulties in general. Some materials are difficult to put on the snow (sludge).
d) Fever	No restrictions	No restrictions	No restrictions	No restrictions	In most cases, dust arises.

Reduce the spread of infection	The desire of birds and insects to nest on the surface of the waste disappears. The use of the waste to feed rodents is limited.	At the optimal thickness overlap, the desire of birds and insects to nest on the surface of the waste disappears. The use of the waste to feed rodents is limited.	Waste can be completely covered and protected against the attraction of the birds, insects and rodents. Operators must protect themselves against pathogens.	Waste can be completely covered and protected against the attraction of the birds, insects and rodents.	To achieve efficiency it's necessary to place the material of optimum thickness.
Fire-fighting effect:					
a) Ignition	Most of the materials are not easily flammable. Some are flammable.	Some materials are flammable, some are not. Before use they should be tested with the ASTM D4982.	Flammable	Flammable	Some materials are flammable, some are not.
b) Penetration level of air and landfill gases	Low	Mean*	High	High	From Low to high

Suppress odors and reduce emissions	The most important is to ensure the equal coverage.	The most important is to ensure covering by optimum thickness. Gases permeability testing is possible with ASTM E96 / E96M.	When the landfill is covered, the odors and emission of gases are minimal, and when opened they spread again. Gas permeability testing of coating materials is possible with ASTM E96 / E96M.	The odors and emission of gases are minimal. Gas permeability testing of coating materials is possible with ASTM E96 / E96M.	Depending on the thickness of the coating material and the compaction coefficient. Some materials, such as sludge, themselves have the smell.
Dust reduction	Reduces	Reduces	Reduces	Reduces	Most raw materials produce dust.
Prevents the light fractions of the waste fluttering in the wind	Yes	Yes	Yes	Yes	Some masses are easily dispersed by the wind.
Reducing the water infiltration	Some types of foams do not infiltrate water during moderate-intensity rain after polymerization.	Water does not infiltrate after polymerization.	When the Polygon is covered, the water does not infiltrate, and when the cover is opened, the infiltration occurs.	It's very effective in preventing the water leakage.	After compaction of some inert materials, there is no infiltration, but some, on the contrary, freely pass water.

Influence on filtrate leakage and landfill gas emission at the Polygon	Has no effect	Has no effect	It has no effect until it gets into the waste.	Does not affect if the used material is degradable. It can affect if the used material is non-destructible.	Clay soils, cement, slag and similar materials significantly impede the seepage of water on the Landfill and the release of landfill gas.
Service life	Depending on the foam type, from 15-20 hours to 3-7 days.	Up to 14 days.	Some have 20 to 30 days and some have 10 to 12 months.	Depending on the supplements and conditions of use, may be from few days to several months**.	Different. Some materials have no expiration date.

* Some materials with the water permeability of $4.16X10^{-9}$ m/s also exhibit the low gas permeability.

** Best materials use duration is 18 months.

Of all the types of intermediate covering, listed in Table 3, the most effective are the covering with ***Sprayable Coating Materials***. Although it requires the special technology mixing and the use of special equipment, the use of this material on the Polygon is also economically effective. The technology was first developed in the United States 40 years ago, and throughout this time it has been refining its technology as well as improving the applied machinery. For detailed information on the spray liquid coatings for the use of intermediate coverings of compacted waste in the active cell of the Landfill, see Appendix 1.

Spray coating materials used for the waste isolation

This technology allows the waste to be covered with the thin, uniform coating that completely replicates the shape of the surface, with minimal cost and high efficiency. Due to the small thickness of the intermediate coating, this overlap method significantly reduces the capacity of the Polygon.

Advantages of the technology

The main advantages of spray coating materials over the friable insulation materials are:

- ✓ Up to 20% of the actual landfill capacity increase by reducing the intermediate insulation thickness to 15-25 cm;
- ✓ Avoiding the Light fractions of the waste fluttering in the wind and reduce dust formation;
- ✓ The spread of the unpleasant odors from the landfill is reduced and no emission of the greenhouse gases (biogas) into the atmosphere is observed;
- ✓ Extraction of gases from active cell of landfill improves;
- ✓ The amount of infiltrate produced and the risks of infiltration are reduced;
- ✓ Improves the uniform distribution of leachate into the waste during recycling, as well as their licage into the drainage system for collection;

- ✓ Landfill slopes stabilization is improved, and therefore the risk of the slipping/erosion is reduced;
- ✓ Insect reproduction in the inner layers of the landfill becomes difficult, reducing the attraction of birds and rodents;
- ✓ The cost of fuel, human and technical resources used for waste insulation are reduced.

The basic principle of technology

The technology is based on the principle of liquid spraying of material on the surface of the waste. Since the material itself is not liquid and most of it does not dissolve in water, it would be more appropriate to speak of the pulp emission consisting of coating material and water. The presence of water allows the preparation of pulp in various water-soluble additives in order, for the material to acquire the properties, required to accomplish the task.

Fig. 26. Pulp Making Machine ADC

For spraying onto the surface of the waste, pulp is prepared in an ADC Machine (Fig. 26). The machine is the tank with one or more shafts with blades for mixing the pulp. The mixture from the tank is piped to the pump, delivering the pulp under pressure to the sprayer. Most often, ADC machines are the modification of the hydraulic sowing machine used for sowing grass to protect the soil from erosion. The mixture can be sprayed either using the water pump mounted on the deck of the car, or using the hose, if necessary to process the small areas or those areas where the stream coming from the water pump does not reach.

Fig. 27. Pulp dissipation process on the waste surface

Achieved results by using Spray coating materials

Reducing the Light fractions of the waste fluttering in the wind

The scattering of light fractions of waste, caused by wind, pollutes the environment, the Polygon and its surrounding perimeter and is one of the most important factors of the population discomfort of the surrounding settlements.

During the wind, the movement of light fractions is hindered by the fact, that during spraying the water-saturated pulp coating, which has the significant specific gravity and exhibits good adhesion to various materials, during contact with light particles (plastic bags, etc.) using its constituents binders, combines them into larger fractions. The dense particles fall under the pulp layer, and their dispersion by air masses no longer occurs.

Water from the pulp evaporates and polymerizes. He creates the film that sticks to the waste and repeats their shape. The resulting film is strengthened by cellulose fibers in the pulp (Fig. 28).

Fig. 28. The waste surface without cover (left) and with the cover (right)

Increasing the landfill capacity and reducing the landfill operating costs

Using the traditional method isolating the waste by covering it with soil (and other bulk materials) layer with the thickness of 0.2-0.3 m, reduces the actual capacity of the landfill and ultimately shortens the life cycle of the landfill (Fig. 29). Use of the new technology in this regard is particularly advantageous, because the obtained results can be effectively achieved with respect to the other factors. The increase in landfill capacity potentially reduces the costs required to build the new one, as well as to close the old landfill and maintenance it after the closing.

The use of friable materials, even at their relatively low cost, is associated with the high cost of transportation and the mobilization of equipment and human resources needed to process it. For example: to cover the waste area of 1000m^2 with the 0.2m thick friable inert material, it's necessary to supply and distribute 200 m^3 of materials using machinery. Depending on the type of material, its mass varies from 180 to 300 tons. To cover waste of the same of 1000 m^2 area by spraying, it's necessary to use from 0.15 to 1.1 tons of materials, which is cheaper than inert materials.

Fig. 29. Increased the capacity of landfill

With regard to increasing the capacity of the landfill, we can say that the use of Spray coating material for waste isolation will increase the amount of waste in the landfill by 10-25%. Consequently, the landfill filling period will also increase and the associated costs will decrease. According to calculations, using the new technology, it's possible to achieve the 15% increase in the capacity of the III cell.

Reducing the generation of leachate

For the waste insulation the Spray Coating Materials are used on the Polygon in daily mode. It forms the thin, but sufficiently dense polymerized film on the surface of the compacted waste, which prevents the seepage of sediments inside and, therefore, prevents the formation of large amounts of the leachate.

During developing new technologies and precisely adapting the content of Spray Coating Materials on the Polygon, the other obstacles are also taken into account, and with the help of the various additives, these properties are improved. The additives can be added depending on weather conditions and current needs of the Polygon operator. In addition to daily covering, the operator can use medium- and long-term coatings, that have the long service life and appropriate water and gas permeability values.

NWCI materials allow creation of the spraying coatings with the water permeability of $4.16X10^{-9}$ m/s. The low penetration of the water reduces sediment penetration into landfill waste layers, thereby reducing creation of infiltration. The penetration of the atmospheric precipitation is reduced by the following two factors:

a) ***Cellulose mulch,*** which is the major component of the material, can absorb water up to 7-8 times its own dry weight. The 1 m^2 surface coverage consisting of the 70-80 grams weigh cellulose mulch, can absorb the 0.56-0.64 L of precipitation, which corresponds to 0.56-0.64 mm;
b) The coating material contains ***Binder Substances*** that form the polymerized film on the surface of the waste. The film facilitates the water drainage from the surface of coatings and reduces its penetration into the layers of the Landfill.

Based on the foregoing we can conclude, that use of Spray Coating Materials reduces infiltrate formation by up to 25%. It should also be noted, that such the result can be

achieved not only by using appropriate insulation material, but also by complying with the necessary waste compacting operation conditions (maximum reduction in working area) as recommended by other guideline documents ("Landfill Gas Control-Guidance on the landfill gas control requirements of the Landfill Directive").

Reduce the emission of landfill gases into the atmosphere, reducing risk of the fire

The complexity of the composition of landfill gases determines the need for their collection and appropriate management at the Landfill. Up to 50-60% of methane content in the biogas shows its strong greenhouse effect (up to 30 times stronger than have carbon dioxide). To the small extent, but still, landfill gases contain components of various toxic properties. The explosion hazard is also important, when biogas (containing 5-15% methane) interacts with atmospheric oxygen. This risk is high during underground work in sewer systems, drainage systems and other piping systems in landfills or in their vicinity. Methane content in biogas increases the risk of fires on the Polygon. No less important is the fact, that migration of the landfill gases into the waste layers can lead to its uncontrolled accumulation and subsequent explosion. Due to the up to 1% hydrogen sulfide (H_2S) content, landfill gases have an unpleasant odor, which also causes discontent of people.

The aforementioned circumstance demonstrates the need for the effective system of landfill gas collection and management in the modern world. Especially considering its potential as the alternative fuel, that makes biogas the valuable product and the source of income for the Polygon.

Spray Coating Materials forms the thin, but sufficiently dense polymerized film on the surface of the compacted waste, which not only prevents the seepage of precipitate inside and, therefore, prevents the formation of large amounts of the leachate, but also prevents the emission of waste gases into the atmosphere and the penetration of air into the deeper layers of waste. So, the covering also reduces the risk of fire at the landfill.

Improvement of the degasation system performance

The use of Spray Coating Technology facilitates the process of landfill degasation and simplifies the system operations. The layered structure of the cell waste at the Landfill, with regular isolation with Friable Inert Materials, is shown on the Fig. 28 in vertical section.

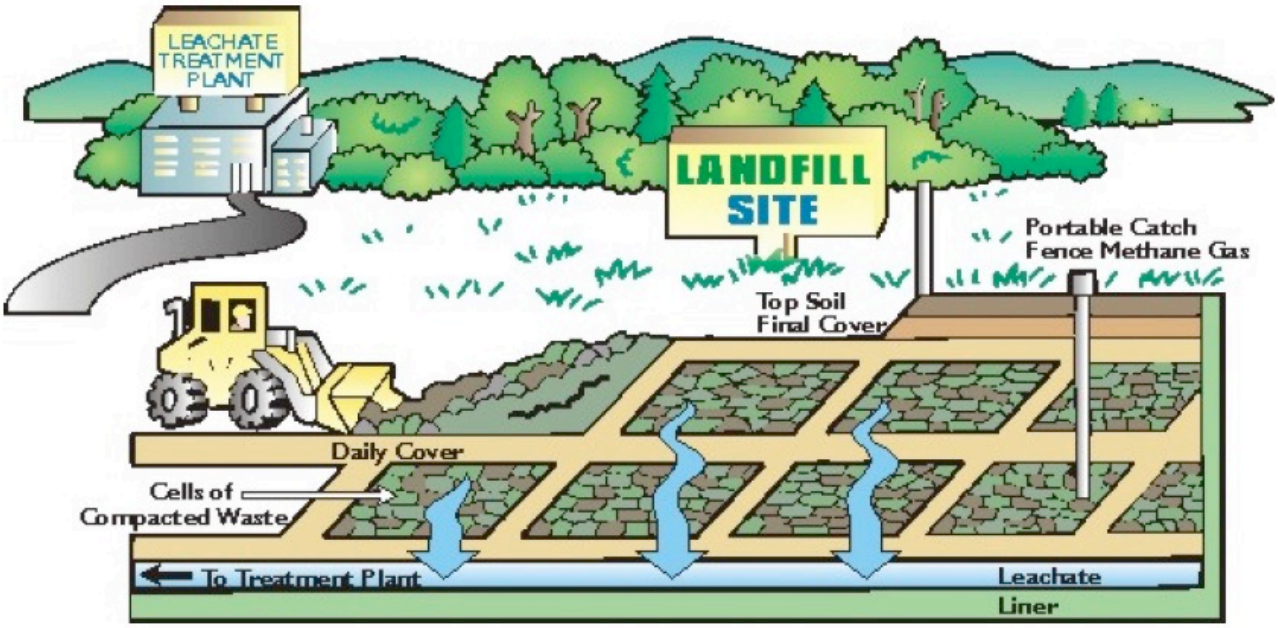


Fig. 30. Vertical section of the Polygon cell

The permeability of gases through the degassing system depends on the insulating materials of the coatings. Since, in Spray Coating is used biodegradable materials, this eliminates its negative impact on gas permeability, and ultimately the cell content becomes the homogeneous structure. As the result, the degassing process is greatly simplified.

Improvement of the landfill leachate recirculation

Notably, another noteworthy significant advantage of Spray Coating Technology compared to the traditional Friable Inert Coating technique. As noted in the previous chapter, Spray Coating improves the performance of the drainage system of the Polygon,

prevents the creation of wetland areas, that impede the operation of equipment and personnel during landfill operation.

Studies and experiments take place in 1999-2001 by the team of researchers from Fukuoka University and Kyushu University in Japan, show that the daily use of insulating coatings containing the cellulose mulch evenly distributes in horizontal direction the infiltration in the landfill cell of Polygon. While, coating the waste with Soil layers leads to the uneven distribution of the infiltrate and its accumulation at the bottom of the cell and the waste layers.

Reducing the attraction of birds, rodents and insects to the landfill

The use of Spray Coating Technology implies the adding of the additives in cellulose mulch, that reduce the attraction of birds, insects and rodents to the Polygon, as well as neutralizing unpleasant odors. In addition, the active reproduction of the insect in the active cell are reduced.

Prevention of the slipping mass of waste from the slopes of the cells

The Spray Coating Technology is based on Grass Hydroseeding Technology which is widely used against soil erosion. The bonding materials used for waste covering have the much higher anti-erosion properties, as well as the strong adhesion to different materials after the polymerization. It very well stabilizes the surface layer of the waste, and at the same time, has the very high water resistance. For example, the long-life coating, consist from NWCI ConCover180 material retains mechanical strength underwater for up to 72 hours.

Due to high water resistance, the coating prevents excessive moisture of the top layers of the waste on the Polygon even during intense precipitation, which also reduces the risk of slippage. The uniform and even distribution of the infiltrate in the horizontal plane avoids excessive moisture accumulation at the bottom of the slope, which also ensures their stability.

The use of Spray Coating Technology complexly resolves the number of problems related to landfill operation.

Spray coating materials

Spray coating materials must meet the following standards:

- ASTM D6523-00 "Standard Guide for Evaluation and Selection of Alternative Daily Covers (ADCs) for Sanitary Landfills";
- ASTM D6826-05 "Standard Specification for Sprayed Slurries, Foams and Indigenous Materials Used As Alternative Daily Cover for Municipal Solid Waste Landfills".

Spray coating materials are divided into the following groups:

The main component of the Spray Coating Materials

The main component of the covering material is the pulp, which forms the basis of the coating at the same time. It basically represents the fibrous mass with good the hygroscopic ability. The fibrous structure of the material is important for the formation of the continuous uniform film on the surface of the waste. The ability to absorb water helps to obtain the desired consistency and move the additives dissolved in the water to the surface of the waste, but at the same time prevents it from seeping into the waste layers.

The most widely used material is the cellulose mulch, which is made from well-shredded newspapers (waste paper) or, relatively less often, from the wood fibers. The manufacture of the paper mulch is relatively inexpensive than from wood fiber, although the latter has longer and durable fibers, which increases the internal density of the coating, decomposes longer, and is more suitable for long-term coating.

One of the most important requirements for materials is their compatibility with equipment. The solid particles, larger than 2 mm size must not be present in the pulp, as they can damage the pumps and damage the spray devices. It is also unacceptable plastic content in the pulp that does not absorb water and is not biodegradable. Experience has shown, that the cellulose mulch can be used as the key component for all types of insulationg coatings.

The bonding component of the Spray coating materials

The bonding components is the so-called glue, the main function of which is to ensure the adhesion of cellulose mulch to waste and to ensure the strength of the film after polymerization. The bonding components also provide the reduction of the air and water permeability of the covering.

The bonding components should not contain cement, ashes and the substances, containing them. They dramatically alter the pH of the area, creating an alkaline area that is not conducive to the bacterial flora working in the anaerobic degradation process.

The cement-containing binders also form the solid, fragile crust, which cannot adequately containment of the landfill gases. It should also be noted that the systematic use of cementitious coatings promotes clogging of the perforated pipes of the leachate system, which impedes the normal operation of the landfill and increases rehabilitation costs.

The bonding components should be environmentally safe and biodegradable. As the binders typically are used the clay, biodegradable organic substances, polymers of natural origin, and other inert materials.

The types of the Spray Coating Materials

The bonding component of the coating mainly determines the durability of the coating used. The following types are distinguished:

- ✓ Short-term Coating (up to 21 days of service). Used for daily overlays. It is the cheapest and its rainfall resistance may be improved by appropriate additives;
- ✓ Medium-term Coating (6-9 months). They are used to cover temporarily unused areas of the Polygons. They also used as the daily coating during heavy rainfalls. These tipe of coverings are erosion-resistant and can be used to protect against the cell erosion. They characterized by the low air and water permeability;
- ✓ Long-term Coating (service life up to 18-24 months). They are used to overlap the Polygon cell slopes. They characterized by very high resistance to erosion and the lowest permeability of water and gases. it should be noted that, that they are also used as the alternative to geomembrane material, for coating the surface of the cell bottom.

These material is the most expensive type of coating, compared to the all above mentioned materials.

Additives to neutralize the odor of the waste, to reduce the number of insects, rodents and birds

Household Waste Landfills, waste composting plants, leachate treatment plants and waste handling stations, municipal waste sorting and recycling centers, are often sources of unpleasant odors and toxic gases.

Neutralizing the odor, associated with Waste Management Processes is one of the most important tasks. Use of odor suppressants reduces unpleasant odor distribution and improves working conditions during Polygon operation.

Neutralize odor by bacteria and enzymes

It's the well-known fact, that bacterial decomposition of the organic fraction in waste constitutes the cause of unpleasant odors. However, there are also certain cultures of bacteria that feed the odor-producing decomposition products, which in turn results in neutralization of unpleasant odors.

Enzymes are proteins, that participate in biochemical reactions and act as catalysts. Today, special attention is paid to the odor neutralizing agents, containing the specially selected enzyme set. They are presented in the form of mixture of bacteria that produce the above mentioned enzymes in the course of their activity. This method is quite effective and provides the long-term solution to the problem.

Chemicals that neutralize unpleasant odors

The odor substances can be influenced by Chemical reagents that can also neutralize unpleasant odors. From the gas phase, the odor-forming gases move to the liquid phase and eventually accumulate in the form of condensate on the ground surface. These chemical reactions are characterized by the wide range of temperatures and their use in field conditions is less appropriate.

Effect of Spray Coating Materials on infiltrate composition

Exposure of cellulose mulch

Studies have shown that the use of Cellulose Mulch Coating has no adverse effect on the infiltrate composition. The typical waste mixture was placed in three identical lysimeters. In the one lysimeter there was the control sample, without intermediate layer, and in the other two there were layers of soil and cellulose mulch added to the same waste mixture.

It should be noted, that the experiments were carried out with pure cellulose mulch, without the binders and additives, that reduce gas and water permeability. Comparison of the infiltrate formed in the cellulose sample, with the infiltrate of the sample containing the soil layer, showed the following changes during the 962-day experiment:

- ✓ Chlorine (Cl^-) ion concentration was decreased by 12.3%;
- ✓ Total organic carbon concentration (TOC) was increased by 9.3%;
- ✓ Concentration of the ammonium ions NH_4^+ was decreased by - 17.4%;
- ✓ Nitrate and the NOx concentrations was decreased by 48.4%.

The results are explained by the more even distribution of moisture and oxygen in the cellulose layer. These is due to the different nature of biochemical processes of the decomposition of waste, which is reflected in the more streamlined process of decomposition during the experiment. Thus, there was no adverse effect of cellulose mulch coating on contamination of the infiltrate was observed.

Impact of Binder Materials

Experience in the use of Binder Components has been around in the world for almost 40 years. These countries include: Australia, Great Britain, Canada, China, Ireland, Italy, Lithuania, Latvia, Mexico, New Zealand. The National Regulation of waste Polygon activity in most of these countries, requires systematic monitoring of the leachate composition in

Landfills. Although no laboratory experiments on the effect of Binder Components on leachate composition were performed, systematic monitoring of leachate composition nowhere has revealed signs of the negative effect of Binder Components on leachate composition.

The high quality Binder Components from the leading manufacturers are fully biodegradable and safe. If we look at the ratio of the mass of waste disposed on the Polygon and the mass of waste whose surface should be coated by Sprayed Materials over the same period, this ratio will be only 0.025-0.030%, i.e. only 25 to 30 kg of binder will be spent on covering every 1000 tons of the waste. The small ratio of the waste mass to the mass of Binder Materials explains these fact, that no new type of contamination in the leachate was observed by any operator who used Spray Coating Material technology with high-quality Binder Materials and carried out the systematic analysis of the leachate.

Equipment required for the production and use of the Spray Coating Materials

The equipment for the preparation of Spray Coating Materials for waste insulation is one of the most powerful hydraulic sowing machines, adapted to perform the similar tasks and equipped with special auxiliary equipment to provide additional work related to the management of the Landfill. For example:

1) Notched (Fig. 31-1) and Spiral (Fig. 31-2) pumps or the super-cavitation type pump that can pump thick mixes under high pressure.

Fig. 31. Volumetric pumps used on ADC machines.

Notched (1) **Spiral (2)**

2) Powerful diesel engines designed to operate full load for the long time;
3) Shredders of the materials in the openings of the loader, and other equipment for quick loading of materials in the equipment;
4) Water pump which allows throw out the stream of water to the distance of up to 50 m (depending on the material) and the hose system for working in hard-to-reach places;
5) The additional tank and the switch to the electric pump for quick washing of pipes or for spraying individual materials to neutralize odors, to scare away birds or to fight insects;
6) Powerful chassis with large wheels, for towing or self moving on the surface of the active Polygon;
7) The possibility of equipping with additional auxiliary devices for individual sprayed materials, for example, to neutralize odors;
8) Ability to equip with winter heating equipment;
9) Equipped with lighting equipment to work in the dark;

The list of basic criteria for selecting the ADC Vehicle is as follows:

1) The area to be covered daily with one full load of the ADC Vehicle;
2) Whether the ADC Vehicle will be used beyond the boundaries of one Polygon of Solid Household Waste;
3) What equipment does the Solid Waste Polygon have for ADC Vehicle transportation?
4) Whether the equipment be used for spraying liquid materials into the air;
5) Whether the equipment be used and stored in low temperature climates;
6) Whether the ADC Vehicle be used at night.

The daily covered area of the landfill and the size of the ADC Vehicle

The area, that should be covered daily is the parameter that determines the size of the equipement. The active working area, where the waste is disposed during the day, can be coated by the equipment, with the mixture for daily spraying. During the operation of the Polygon the work area has no permanent area and size; It may change periodically. Therefore, to select the size of the tank, should be taken the maximum working area and increased by 15-20%. The reserve is necessary, so that it would be possible to cover the

working area without delay. In addition, under the adverse weather conditions (during wind), the material consumption may increase slightly.

Typically, the small tank models with the capacity of 380-650 gallons, don't have the mulch shreders. The such small ADC vehicle can be justified, by the small size of the Polygon.

Factors to consider in selecting an ADC vehicle

The daily covering with insulating material of the Landfill is produced at the end of the working day, after the placement of waste in the cell finished, the movement of garbage trucks is completed and the waste was alredy compacted by the heavy machinery. The landfill technique allows to use the same machinery (bulldozers, frontal loaders) to cover the Landfill with Spraying Materials. In this case, the ADC Velicle is selected according to the area of the whole active zone of the Polygon, depending on the need to cover the surface with one load of machine. However, the disadvantage of this approach is:

- ✓ During the working day, while the waste is placed and compacted in the active chamber, the active zone is not protected for the long time and light fractions of the waste fluttering in the wind;
- ✓ The need to fully cover the active zone with the single workload of equipment, forces operators to purchase large equipment - typically 900 to 1700 gallons in capacity, which is quite expensive;

In order to prevent light fractions from being contaminated by the wind, it's advisable to cover with parallel operation. The Landfill operator should divide the active waste cell into the small sections.

For example: If the Landfill has an active area of the 2000 m^2 and the waste is disposed of between 8:00 and 22:00, or during the 14 hours, then the waste at first should be disposed and compacted on the 1000 m^2 are, between the 8:00 and 15:00. At this time, the surrounding 1000 m^2 area is protected by the previous day's cover, and it's recommended to start covering the waste disposed from 8:00 am to 15:00 pm by the ADC Velicle. At 22:00 it's necessary to begin to cover the surface of the waste, placed from 15:00 to 22:00.

These kinde of work arrangement, allows to reduce the area of the active cell by half, and the Light fractions of the waste fluttering in the wind will be decrease accordingly. Thereby, this allows for the daily coating use the machine with the capacity of 600–650 gallons, instead of 1,100–1200 gallons, which is more compact, lightweight and at the same time cheaper. It should be taken into account, that in the addition to large capacity, large models typically have wider capacities and include something, that smaller models may not have. It should be noted, that the service life of small capacity machines is less and they do not have super-cavitation pumps, which allow the mixture to dissipate up to 50 m; Such machines cannot spill the mixture over 25-30 m, which makes it more time-consuming and forces staff to load cellulose mulch by hand, to use hoses more frequently, to service the machine more often and to repair it frequently. For example, notched pumps used on the such machines require overhaul, or replacement of parts approximately once the year, with daily loads of 1.5-2 hours.

Solid Waste Polygon Technique as an ADC vehicle Selection Factor

1) Dump trucks

Most ADC vehicles are manufactured as trailers for the tractors and other similar equipment and towed onto landfill via wheeled or tracked tractors. In addition, large-diameter tires are mounted on the chassis with the ADC velicle mounted. Often, for these vehicles, as one of the option, offere wheels filled with special gel or rubber foam. On trucks operating on the Polygon, tires are often damaged, so this factor should be also considered when choosing the vehicle.

Fig. 32. ADC Vehicle - trailers

2) SKID performance

This performance means, that the unit is delivered without the trailer, without wheels and without the coupling device. It's designed for the customers who mount the ADC machine on its own chassis. This may be either the stationary unit on the self-propelled chassis, or the use of an ADC Vehicle as the replacement device, for the vehicle equipped with the body replacement system, the type of multielevator and its analogues, which gives the organization using it, greater flexibility in the use of machinery. Examples of the self-propelled chassis, on which are installed the ADC Vehicle are shown on the Fig. 33.

Fig. 33. The self-propelled chassis, on which are installed the ADC Vehicle

It should be noted, another way to install the ADC machine with SKID performence - as the mount on the front loader. (Fig. 34). Such installation promotes to the convenient loading and preparation of the mixture - the unit is mounted on the straight surface, not high from the surface, which facilitates easy loading of materials. Once mixing is complete, the loader hooks the device and turns it into the self-propelled ADC Vehicle. The separate front-end loader is much more maneuverable and has the better pass than trailers, and allows access to places where other equipment cannot reach. During operation, the ADC Vehicle can be rotated to the desired position, due to the maneuverability of the loader, it can climb to the hill for better dispersion and, it can even tilt the tank, for more complete it use.

Fig. 34. ADC Vehicle as the front loader hanger device

Organizing of the Spray Coating Work

The proper organization of the Spray Coating Work requires that all stages of the work be organized with minimal use of the time and resources. The Spray Coating Work process can be divided into the following steps:

1) Receiving, downloading and storing of the materials;
2) Loading the materials into the ADC Vehicle and preparing the pulp for spraying;
3) Transporting of the ADC Vehicle to the Polygon's active cell;
4) Spraying the covering on the waste surface;
5) After the completion of the works transportation of the ADC Vehicle back, for cleaning and washing operations;
6) Washing the ADC Vehicle after the work is completed;
7) transportation of the ADC Vehicle at the storage and/or loading place;
8) ADC Vehicle maintenance and fuel handling operations;
9) Storage of the ADC Vehicle.

Receiving, downloading, and storing of the materials

Spray Coating Materials are supplied in the dry form (pulp) and in the liquid form (pulp additives). Dry materials are delivered in the bags, and liquid materials in the containers of various capacities, including 1040-liter IBC containers. Materials, are usually stacked on the pallets.

1) Material unloading requires the forklift truck with the carrying capacity of at least 1.5 tons;
2) For storage of materials, is recommended use the dry premise with the flat floor, so that the pallets can be easily moved by means of the hydraulic cart; The warehouse should be equipped with the hydraulic trolley.

- ✓ Dry materials can be stored at the temperatures below 0°C;
- ✓ Liquid materials should be stored at the temperature above 0 ° C.

In the warm season, materials can be stored under the canopy, that keep it dry in the rain. Their storage should be arranged as close as possible, to the ADC Vehicle loading and/or parking area.

Load the materials into the ADC vehicle and prepare the pulp for spinning

The loading area of the equipment should be arranged as close as possible to the material storage location. If it's not possible to place the loading area near the premise for storage of sprayed insulating materials, then at the site where the loading is made, the small warehouse of materials should be arranged for the 15-20 tanks of the ADC Vehicle.

The place of loading of the equipment should be equipped:

1) Technical water source with the supply of at least 300 l/min;
2) Lighting of ADC Vehicle deck, small warehouse, access roads to the ADC Vehicle. The deck lighting shall be high and sufficiently bright to allow the operator to visually control the preparation of the pulp from the loading hatch;
3) The place for disposal of the used packaging materials (paper, cardboard, plastic);

The access paths to the device should be such, that the ADC Vehicle can be easily moved along with the clutch, even while driving the backward. It will be convenient, if the place of the ADC Vehicle loading and the place of its storage coincide. In this case, the storage temperature should be above 0°C all the year round, to prevent freezing of water in pipelines, valves and pumps.

Transportation of the ADC vehicle

The ADC Vehicle is transported to the landfill by the tractor if the Polygon operator selects the trailer unit or by the ADC Vehicle self-propelled chassis. The equipment is

transported in accordance with the rules of road safety, safety rules of equipment and internal regulations of the Polygon.

It should be taken into account, that it's undesirable to replace the tractor on the surface of the active cell at the waste disposal site. The tractor, with which the ADC, or the chassis on which it is mounted should be towed, must have sufficient power to reliably move the fully loaded device.

Sprayin of the insulating coating on the surface of the waste

The main method of spraying of the insulating coating on the surface of the compacted waste is to release it from the sprayer located on the deck of the ADC. The auxiliary method is spraying with the hose, which is used only when the desired location cannot be covered from the sprayer installed on the ADC vehicle platform.

While spraying of the insulating coating on the surface is important to ensure timely and accurate movement of the equipment. Therefore, there should be the constant communication between the operator, producing the spraying and the driver, who is driving the ADC-Vehcile. Communication can take place both through the predetermined gestures and with the help of the walkie talkie. The following methods for covering the waste with the use of the sprayer placed on the deck of the ADC Vehicle. are known:

Rain spraying in the calm weather

Most daily spray mixtures are recommended to be sprayed with "Rain" method (Fig. 35), by moving the axis of the sprayer upwards, at the angle to the horizontal so, that the mixture droplets falls freely under the influence of gravity into the separate drops, like rain.

In the case of the correct spraying technique, the droplets drop almost vertically on the surface of the waste. This way achieved the most complete and even coverage without "shadows". In order to increase the coverage area, it's recommended for the operator to continuously adjust the angle of inclination sprayer from the average position within 20-30 degrees. Also recommended, rotational movement of the sprayer along the vertical axis while spraying to the required sector. Usually this sector is 90-120 degrees. The combination of these methods provides the most uniform coverage with the minimal flaws. This method of spraying is the most suitable for light daily mixtures. It's not used for the medium and long-term coatings.

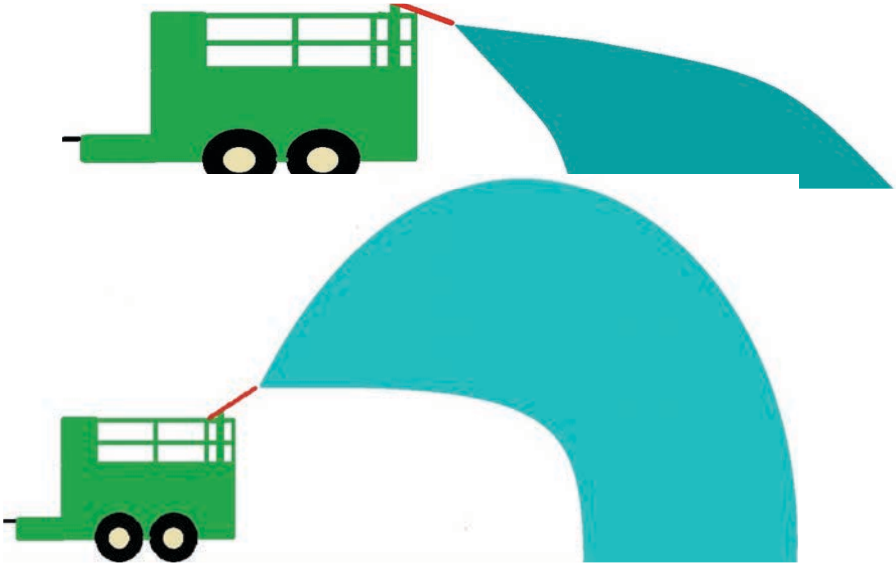


Fig. 35. Sprayed of the insulating coating with the "Rain" method

Directe spraying

Direct spraying (Fig. 36), directing sprayer below the horizontal line, is used for the medium to long-term coatings, and is rarely used for the daily coatings, only when the surface treatment is required near the machine. Using this method of spraying the mixture on the surface of the waste, the coating creates gaps - "shadows" at uneven locations on the opposite side of the cover (Fig. 37) from which the mixture is sprayed. Typically, when the material is sprayed on the cell slopes, the shadows are more likely to form.

If it's impossible to avoid the appearance of "shadows" during spraying, for objective reasons, recommended to perform the spraying in the two stages - Basic and Repeated spraying. Thus, during the Basic spraying, will be covered the most part of the surface, and during the Repeated spraying, the same area will be covered from the opposite side. While Repeated spraying it's advisable to place the sprayer in the position closer to the vertical or bend it downward direction. If the spraying occurs from the area where the "shadows" are, then this will allow the waste to be covered completely at the minimal cost.

Fig. 36. Sprayed of the insulating coating with the Directe method

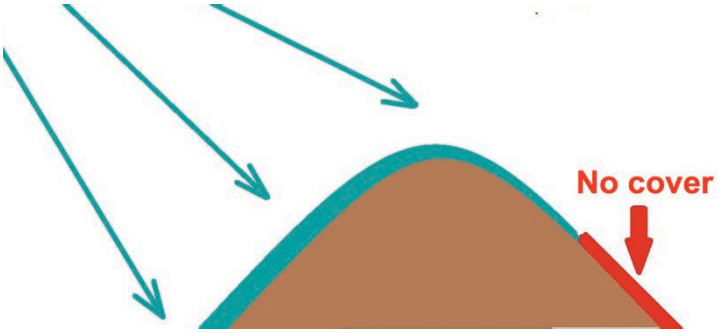


Fig. 37. Creation of "shadows" while spraying

Spraying up and down on the waste slopes

The terasing of III cell, proposed in the first part of the current document, makes it possible to effectively cover them with durable insulating materials. To cover the coating with the best possible quality (continuous and uniform), it's advisable to run from the bottom upwards. In this case, relatively the few "shadows" will form on the slopes.

When covering the surface of the Polygon active zone, is taken into account the fact, that it has horizontal sections on the top of the hill and cannot be processed while working from below. Therefore, for applying daily insulation coatings, it's optimal and recommended to perform works in two stages - from the bottom to top and from the top to bottom. In both cases - from the bottom to top and from the top to bottom - the treatment results in additional movement of the ADC Vehicle, but at the same time, ensures the highest quality of the coating by the insulating layers.

When the mixture is sprayed from the top of the slope, the driver should bring the machine as close to the edge of the slope as possible so that the operator can clearly see the slope. The operator must pay particular attention to the use of the "Rain " technique, as one way of preventing "shadows" from forming.

The spraying properties in windy weather

Spraying in windy weather is characterized by the change in the direction and velocity of the droplets of the mixture. Wind can interfere with the work, or vice versa, help the experienced operator do his work more efficiently and quickly. While spraying insulating mixture against the wind (Fig. 38), if pressure of the sprayer and the sprayer itself selected correctly, can be achieved effect, when the direction of movement of the drop changes near the surface. This helps to avoid the "shadows". The spraying is carried out by sprayer that is in the position close to the horizontal. Excessive emission pressure reduces the size of the droplets, their kinetic energy decreases, and the wind easily moves the droplets out of the processing zone in the another direction. Therefore, it's important to regulate the emission pressure and maintain it at the level, that makes the droplets more heavy. Usually, spraying in windy conditions should not exceed 10 m.

In order to avoid dropping the mixture droplets onto the equipment, it's recommended to work at the angle of 30-60 degrees to the longitudinal axis of the equipment. If it's necessary to work along the longitudinal axis of the machine, the sprayer should be lowered down, and the gun holes should be located horizontally to reduce the height of the jet mixture and to avoid contamination of the equipment by wind.

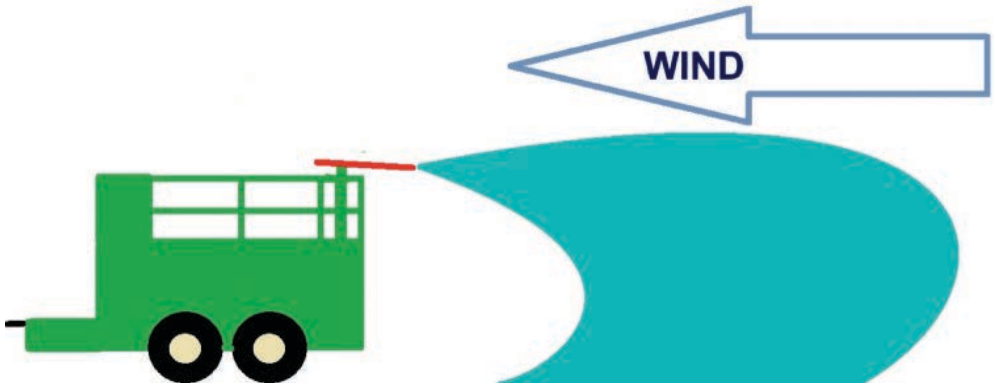


Fig. 38. Spray insulating mixture against the wind

In windy weather, wind power can be used to increase the spray range. This allows to use the fan spray instead of using the direct jet, to spray in remote areas of the working area. Spraying is carried out using the high-raised sprayer and the "Rain" technique is used. To reduce the effect of the wind, direct spraying can be used to provide larger droplets of the mixture.

ADC-vehile washing after finishing the work

After completion of the work, it's necessary to rinse the tank and equipment pipes from the pulp waste. Some types of pulses, especially the coating pulses, that contain water and gas penetration suppressants, after polymerization in pipelines and fittings, can damage the equipement due to clogging in pipelines and/or pump.

Most of the ADC Vehicles have the additional water tank, which is used to rinse the equipment and hoses after completion of works. If the ADC Vehicle does not have the rinse tank, it should be equipped with the latter and rinse of the tank, piping, pump and hoses should be ensured for 15-20 minutes immediately after completion of work, by half-filling the equipement tank by pure water and pumping water into all pipes and hoses that came in contact with the solution.

It's necessary for the equipement to be washed externally, and it should be cleaned up from the pulp and other contaminants, as well as from the waste with the high pressure washer.

Storage of equipment

Storage of the ADC Vehicle is preferable in the rainproof shelter if the temperature does not fall below 0°C throughout the year. In winter, when the ambient temperature is low and there is the risk of freezing water, it's recommended to follow the following procedures for storing the device:

1) Fully empty the water tank and all pipelines from the water;
2) Shut down the stopper designed for the release of water or pulp;
3) The valves should be remain open;
4) Pour 200-300 liters of antifreeze in the equipment tank;
5) Run the engine and pump briefly to allow the antifreeze to pass through all pipelines.

Antifreeze should be removed from the equipement before the use. After washing the equipement under conditions of the storage it's necessary to dry it. Compliance with this condition is mandatory to prevent the corrosion of the equipment.

Work with equipement in winter conditions

The experience of using Spray Coating Technology in countries where the air temperature is below 0°C (USA, Canada, Latvia, Russia) shows, that spray coating on the waste surface can be carried out up to -20°C. However, the following conditions should be met:

- ✓ The temperature of the ADC Vehicle prior to loading (storage and loading temperature) shall not be less than +15°C;
- ✓ Pulp-loaded ADC Vehicle staying outside the heated premise should be as briefly as possible, in particular at -20°C - approximately 20 minutes. As the outdoor air temperature rises, the equipement freezing time increases;
- ✓ The equipment deck, handles, trap should be dry, before the equipement moves outside the heated premise, at the low temperature.

There are known cases of ADC Vehicle heating with the electric heaters and liquid fuel heaters. At low temperatures, perform daily work at the landfill with help of the equipment is possible only if there is the heated and warm place for storing, loading and unloading cellulosic material.

Consistent use of Spray Coating technology with other processes, required for landfill operation

The use of spray coatings on the waste surfaces by the operator should be coordinated with other processes, such as procedures for compacting waste in the active waste cell.

The main requirement when using this technology is, if possible even and uniform compaction of the waste on the cell surface. This will help to reduce the cost of insulation materials and obtain the uniform, even coating without the any flawes or shadows. Prior to applying Spraying Coatings, it's recommended to pre-treat the waste surface with the machinery. It should be noted, that it's desirable to well compact large-sized waste and cover it with the relatively small-sized waste.

It should also be noted that the implantation of the Spray Coating Technology in Landfill operations will affect the design and operation of the degassing and leachate systems.

Effective operation of the Polygon requires the coherent and coordinated implementation of the all procedures, ensuring the efficient use of resources.

Sequence of usage of the different types of Spray Coating

1) **Daily Spray Coating** on the surface of the active cell of the Polygon should be carried out at the end of each working day, and if the temperatures will be below +5°C - at least once every 3 days. The compacted waste surface should be completely coated with the ADC Vehicle. The full load area of the ADC Vehicle is determined by the material manufacturer and/or material supplier. The prescription of mixtures for daily coatings developed by the supplier of insulation materials shall be observed; Weather conditions should be taken into account. Mixtures intended for use in the rainy weather should include additives that reduce the permeability of the coating. As part of daily coatings, it's advisable to add supplements that neutralize the unpleasant odor from waste, reduce the attraction of birds and rodents, and inhibit insect reproduction. These types of the supplements can be seasonal in nature.

2) **Medium-Term Coatings** are used on waste surface areas, where no work is foreseen or no heavy equipment intend to move for the period of time, that goes beyond the daily coverage maintenance (7-21 days) and, at the same time, not exceed the 6 months. Insulating coatings should be sprayed without the defects, in the continuous layer, to prevent the penetration of the water and gases. The full load area of the ADC Vehicle is determined by the material manufacturer and/or material supplier. The prescription of mixtures for Medium-Sized Coatings, developed by the supplier of insulation materials shall be strictly observed; Basically, medium-term coatings are applied to the horizontal surfaces of compacted waste layers. In case of damage of the coating, it should be repaired;

3) **Long-Term Coatings** are applied to landfill cell sites, where all work is completed and the surface will not be broken for the long period (6 months to 1.5 years). Insulating coatings should be sprayed without defects, in the continuous layer, to prevent the penetration of the water and gases. The prescription of mixtures for Long-Sized Coatings, developed by the supplier of insulation materials shall be strictly observed; Long-lasting coatings are mainly applied to the surfaces of the lateral slopes of the Polygon cell and are covered after the

compacting of the waste layer is completed. In case of damage of the coating, it should be repaired;

When applying Spray Coating to the same areas of the Landfill, the sequence of procedures is as follows:

1) Wast disposal;
2) Use of the daily coverage after completion of compacting;
3) Laying of the vertical and horizontal channels of the degassing system or horizontal pipes of the Leachate Recirculation System;
4) Placing of the Medium-Term Coverage. If the construction work of the Degassing and Leachate Recycling System was not carried out within 21 days after the formation of the site, the Medium-Term Coating should be applied before the start of the work and will be resumed after completion of the works. In addition, it can be use Medium-Term Coating of the such composition, which has the service life of 60-90 days;
5) Six months after the Medium-Term Coating was applied, the Long-Term Coating should be applied if the surface is the surface of the lateral slope, or for other reasons it will not be used for more than 6 months. The type of coating used depends on the stage of Polygon cell formation and the subsequent purpose of this surface.

Schematically, the sequence of Spray Insulating Coatings at different sites of the Polygon, depending on the stage of cell formation, is shown in Fig. 39:

N- Formed layer of waste;
N-1 – Previously formed waste layer;
D – Waste disposal site (active zone);
D-1 - Waste disposal site day earlier;
D-2..9 – Waste disposal site 2... 9 day ago;
D-3 – Waste disposal site 3 day ago;
1 – Active zone, not covered;

2 – Daily coating;

3 - Medium-term coating;

4 – Long-term coating;

5 - Laid pipes in the N-1 layer of Leachate recirculation System;

5 – Horizontal channels of Degasation System laid in the N layer;

6 - Horizontal channels of Degasation System laid in the working zone.

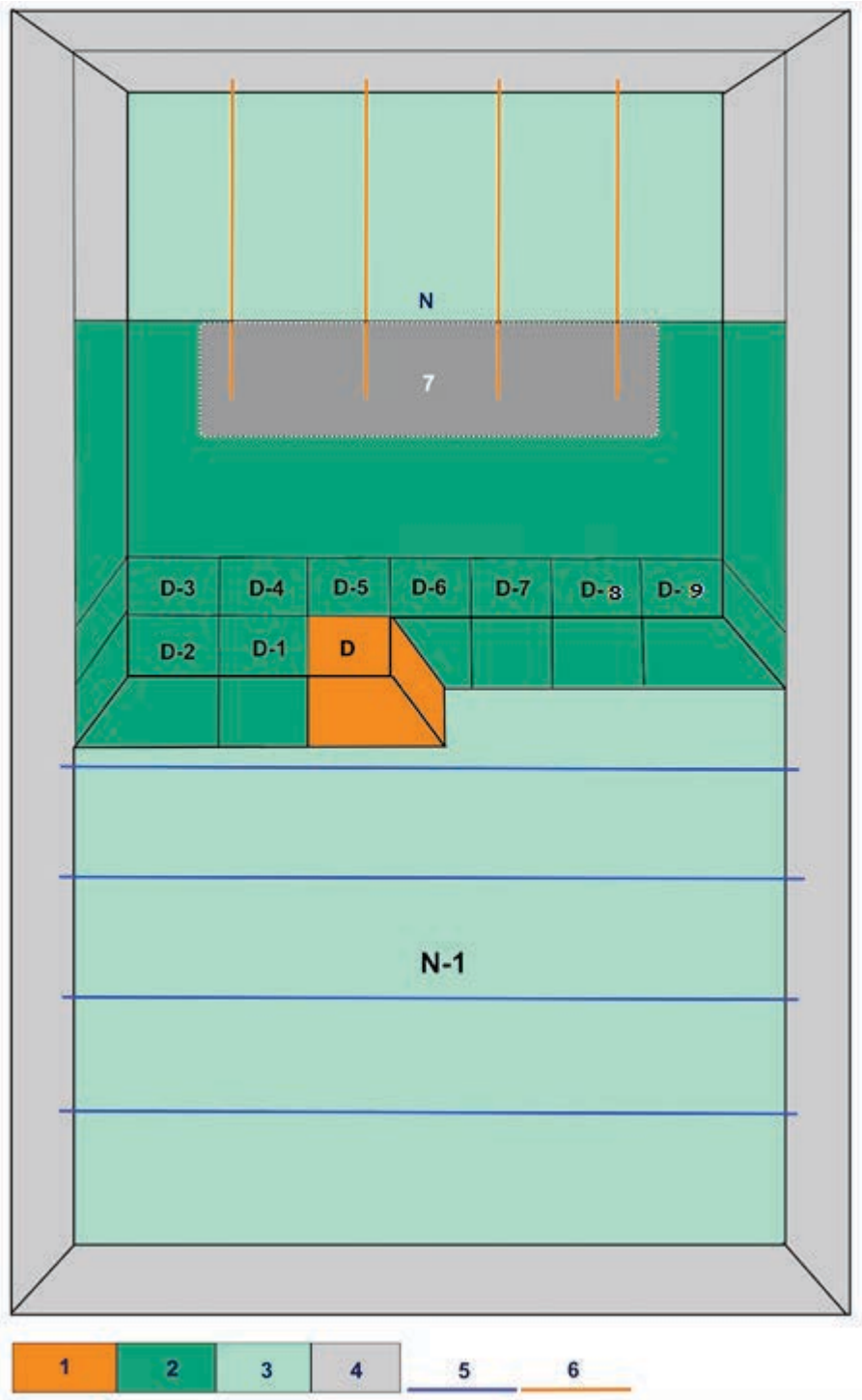


Fig. 39. Covering types depending on the stage of cell formation

Simultaneously with the formation of the terraces on the slopes of III cell, it's possible to begin spraying the permanent impermeable coating on the cell surface. These works can be carried out in stages. Before beagining of the spraying permanent impenetrable coating works the degassing and Leachate Recirculation Systems Infrastructure Construction Work should be completed.

Bentonite layer with the permeability of 1 X 10^{-11} m/s can be applied as the permanent impermeable layer for the final disposal of waste in the cell. The bentonite layer is formed on the cell surface in accordance with the standard constructive and technological solutions developed by the manufacturer. The last recultivated surface should be sown by the perennial grass cover - (seed consumption is 40 g/m^2), which protects the soil from erosion. It'is advisable to sow grass by hydropower method using the wood fiber based mulch, which should not be lower than the BFM-bonded fiber matrix, with the minimum application rate of the 3800 kg/ha and additives, that improve seed germination and stimulate the plant root system.

Appendix 2

The Ortho photo of "Didi Lilo" Polygon

The Ortho photo of III cell of "Didi Lilo" Polygon

The above-mentioned task will be carried out by the working group of Geo-Consultants. The group is comprised from the local and foreign experts, who are highly qualified specialists in the field.

In preparation of this report were involved the the following experts:

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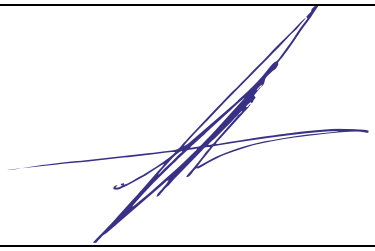
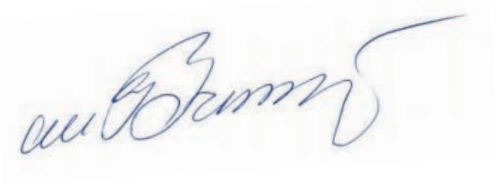
Janis Abeltins	Project Mnaager	
Maris Brems	Deputy Project Manager	
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